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Wide Area Decontamination: CB Decontamination Technologies, Equipment and Projects – Literature Search and Market Survey

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Final Report - January 1998 – March 1999

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FOR THE DIRECTOR

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13. ABSTRACT *(Maximum 200 words)*

The objective of this literature search and market survey effort was to conduct a detailed literature search using the CBIAC, DTIC and other available CB related information sources of CB decontamination activities. The literature search identified US and international equipment, technologies, and research and development (R&D) efforts performed in the area of CB decontamination. In conjunction with the literature search, a market survey was conducted that identified capabilities of currently fielded CB decontamination equipment, emerging technologies, and past, present, and proposed future CB decontamination related efforts. Furthermore, an "out-of-the-box" study was conducted that addresses the use of ancillary commercial equipment that may have a tangential purpose but potentially may be applied to CB decontamination efforts.

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EXECUTIVE SUMMARY

"I believe the proliferation of weapons of mass destruction presents the greatest threat that the world has ever known. We are finding more and more countries who are acquiring technology — not only missile technology — and are developing chemical weapons and biological weapons capabilities to be used in theater and also on a long-range basis. So I think that is perhaps the greatest threat that any of us will face in the coming years."

Secretary of Defense Cohen, 1997

The United States is enjoying a period of relative peace and security. The threat of global war has diminished with the breakup of the Former Soviet Union. Former adversaries now cooperate on a wide scale of issues. However, there are still some significant challenges. Perhaps the most serious challenge involves the proliferation of nuclear, biological, and chemical (NBC) weapons of mass destruction (WMD) along with a number of nontraditional, transnational, and unpredictable threats to our security.

During this period of relative stability, the U.S. military has undergone a shift of military strategy and a concomitant realignment and resizing of the force structure. As a result, the military has withdrawn from many overseas bases to locations within the U.S. while retaining responsibilities to respond world-wide as the situation demands.

Events such as the Aum Shirinkyo Tokyo sarin attack and the World Trade Center and Oklahoma City bombings have shown that relatively small acts of terrorism have significant impacts. In particular, the use of a nerve gas or a chemical agent can inflict mass casualties, instill mass hysteria, and undermine the morale of the armed services and the political will of the nation. With the withdrawal of military forces back to U.S. locations, nation-states could support terrorist groups employing NBC WMD in an asymmetrical manner. Rather than face the U.S. directly, these nation-states may target force projection sites to deny the use of an airport or seaport, or to delay and hinder the deployment of armed forces to a troubled region. Thus, through the use of a small group against a larger force (asymmetric) far from the region of concern (transnational), the outcome of the conflict could be favorable to the aggressor.

This scenario has been examined by the Chem War 2000 and Chem/Bio 2010 studies that have indicated that significant disruptions could occur should an enemy use relatively small quantities of chemical and biological weapons against airports, seaports and logistical bases. As a result, decontamination processes, techniques, and equipment have received increased emphasis to return these sites to normal operations as quickly as possible. While the traditional focus of decontamination activities have dealt with unit personnel and equipment, this potential threat has enlarged the scope of these activities to encompass landing strips, loading docks, equipment bays, aircraft hangers, administrative buildings, and residential areas.

To address this issue, a new materiel development program, the Joint Service Fixed Site Decontamination Program, was established in FY99. In FY98, this study, among other activities and studies, was initiated to provide information for use by the Program Office to develop their program.

The purpose of this study, sponsored by the U.S. Joint Service Materiel Group (JSMG), Decontamination Commodity Area, is to conduct a worldwide Chemical and Biological (CB) Wide Area Decontamination Literature Search and Market Survey. The results of the effort will provide a detailed assessment of existing equipment and technologies that may meet the CB wide area decontamination needs of U.S. Forces and domestic emergency responders.

Battelle conducted a detailed electronic literature search of several military and commercial technical databases to identify relevant U.S. and international equipment, technologies, and research and development (R&D) projects performed in the area of CB decontamination. The literature search was structured into the functional areas listed below:

- Skin and Personal Equipment Decontamination
- Exterior Equipment Decontamination
- Sensitive and Interior Equipment Decontamination
- Large Area Decontamination
- Decontaminants
- Specific Decontaminants
- Decontamination
- Specific Decontamination Processes
- Proactive Decontamination
- General Keywords

Using the identified keywords, over 20,000 records were identified from the U.S. Army Chemical and Biological Defense Command (CBDCOM), Chemical and Biological Defense Information Analysis Center (CBIAC), Defense Technical Information Center (DTIC), and Dugway databases. Results of each search were received electronically, technically reviewed, and relevant records were then downloaded into the Decontamination Database developed by Battelle using Microsoft Access. The database was delivered as a supplement to this report.

To further identify relevant U.S. and international equipment, technologies, and research and development (R&D) projects in the area of CB decontamination that may not have been adequately covered or identified by the Literature Search, Battelle conducted a detailed Market Survey. The Market Survey was divided into two elements: military (U.S. and international) equipment manufacturer's and commercial/industrial sources. As part of the Market Survey, Battelle reviewed Jane's NBC Defence Systems publications and identified CB decontamination equipment from over 25 different countries. Battelle also conducted a detailed Internet search using Metacrawler of industrial and international military home pages. For additional commercial/industrial sources of CB decontamination technologies and equipment, Battelle searched the Thomas Register of American Manufacturers.

Each of the vendors identified through the Market Survey were directly contacted via facsimile or electronic mail to acquire additional information on the equipment identified. For the CB decontamination equipment identified, the equipment name, manufacturer, and system capabilities were entered into a separate element of the Decontamination Database and used to support the development of this report.

An "Out-of-the-Box" study, performed by Charles W. Williams Inc, focused on identifying, through non-traditional search strategies, potential "crossover" technologies used in other applications that may be applicable for use in CB decontamination. Using the DIALOG and Reuters News Service commercial databases, potential crossover technologies were identified and assessed. The results were then formulated into potential integration concepts.

At the conclusion of the Literature Search, Market Survey, and the "Out-of-the-Box" Study, Battelle performed a detailed assessment of all the results identified. The objective of the summary assessment was to assess the technologies and equipment identified to determine those that offered the most promise for meeting the immediate needs of the Joint Service Fixed Site Decontamination Program. The summary assessment also included a detailed examination of the potential use of combining the technologies and equipment identified into hardware solutions for immediate implementation.

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Chemical and Biological Wide Area Decontamination
Literature Search and Market Survey

1.0 Background

The U.S. Joint Service Materiel Group (JSMG), Decontamination Commodity Area has sponsored the conduct of a worldwide Chemical and Biological (CB) Wide Area Decontamination Literature Search and Market Survey. The purpose of this effort is to survey and analyze existing equipment and technologies that may meet the CB wide area decontamination needs of U.S. Forces and domestic emergency responders. Information collected as a result of this study has been compiled into a database that can be used to support upcoming decontamination program activities. The need for improved technologies and equipment for CB decontamination has become a priority for the Department of Defense (DoD). With the increased threat from third world countries, as well as the increase in terrorist activities, incidents involving CB WMD have become a highly probable occurrence. As such, improved decontamination methods and technologies are essential for the protection of the warfighter and the civilian community.

2.0 Objective

The objective of this Literature Search and Market Survey effort was to conduct a detailed literature search using the CBIAC, DTIC and other available CB related information sources of previous CB decontamination activities. The literature search identified U.S. and international equipment, technologies, and research and development (R&D) efforts performed in the area of CB decontamination. In conjunction with the Literature Search, a Market Survey was conducted that identified the capabilities of currently fielded CB decontamination equipment, emerging technologies, and past, present and proposed future CB decontamination related efforts. Furthermore, an "Out-of-the-Box" study was conducted that addresses the use of ancillary commercial equipment that may have a tangential purpose but potentially may be applied to CB decontamination efforts. The results of these studies have been collected in a Decontamination Database that is described and summarized in this report. The database is included on a CDROM that is included as a supplement to this report.

3.0 Definition of Terms

This section provides the reader with a consistent definition of terms for use throughout this document. Although no "official" definition is known to exist for each of these terms, the terminology defined below will provide users of the document with a common understanding of the functional intent of the terms.

3.1 Decontamination

Decontamination is defined as the process of removing or neutralizing a surface hazard resulting from a CB attack.

3.2 Decontaminants

Decontaminants are physical substances used to destroy, reduce or remove CB agent contamination to an acceptable level.

3.3 Decontamination Technology or Process

A scientific technology or process that can be employed to reduce or remove CB agents to an acceptable level. All decontaminants that chemically or biologically destroy, reduce, or physically remove CB agents fall under this category.

3.4 Decontamination Equipment

Decontamination equipment is defined as any piece of equipment that is employed to deliver a CB decontaminant or physical process to the item to be decontaminated.

3.5 Decontamination Projects

Decontamination projects are specific U.S. and international Government funded activities designed to develop a piece of CB decontamination equipment or a CB decontamination technology to a point where the item can be fielded and employed by warfighters.

3.6 Skin and Personal Equipment Decontamination

Skin and Personal Equipment Decontamination refers to the ability to decontaminate CB agents from human skin and military personal equipment that may pose a direct threat to human health through direct contact. Decontamination of the skin must quickly and efficiently remove the CB agent without causing damage to the skin. Skin decontaminants can either destroy the CB agent on the skin through chemical or biological reactions or physically remove the agent from the skin.

Personal equipment decontamination refers to the ability to decontaminate CB agents on personal equipment that is carried by the warfighter and may come into direct contact with a warfighter's skin. Examples of personal equipment include clothing, helmet, load bearing equipment, boots/shoes, weapon, and equipment worn by the warfighter or equipment that is routinely man-portable.

3.7 Exterior Equipment Decontamination

Exterior equipment decontamination refers to the ability to decontaminate CB agent from the exterior surfaces of military equipment to include both large and small items. Examples of equipment and exterior equipment include tanks, armored personnel carriers, aircraft, ships, shipping crates, and artillery pieces.

3.8 Sensitive Equipment Decontamination

Decontamination of sensitive equipment involves the removal of CB agent from the surfaces of electronic equipment such as communications equipment, fire control equipment (computers), and navigational equipment. Sensitive equipment is defined as that equipment that cannot be exposed to liquid aqueous decontaminants and strong oxidizing or caustic solutions without a degradation of the performance.

3.9 Interior Equipment Decontamination

Decontamination of interior equipment involves the removal of CB contamination from the interior of a vehicle, aircraft, or shelter using a decontaminant that does not cause performance degradation. The interior of many pieces of military equipment require special consideration during the performance of decontamination operations, since the interior of the equipment is where personnel operate and therefore, are most likely to contact contaminated surfaces while operating in a reduced level of protection.

3.10 Large Area Decontamination

Large area decontamination involves the removal of CB contamination from large areas of land and terrain as well as large-scale items such as roadbeds, air strips, cargo loading docks, and multiple buildings. Large scale items require special consideration during the performance of decontamination operations since these items are most likely to become contaminated during a CB warfare attack due to the extensive surface area.

4.0 Technical Approach

The technical approach followed by Battelle to perform the Wide Area Decontamination Study consisted of three parallel efforts: Literature Search, Market Survey, and the "Out-of-the-Box" study. The literature search consisted of an in-depth search of four Government databases to identify relevant technical information related to the field of CB agent decontamination. In addition, a Market Survey was performed to identify the different decontamination technologies, equipment, and projects currently in use for CB agent decontamination. This effort utilized the information identified during the literature search and also included an extensive Internet search to help identify decontamination equipment. The final effort consisted of an "Out-of-the-Box" study performed by Charles W. Williams, Incorporated. This study addressed "Out-of-the-Box" ideas that may be applicable, either independently or in combination with other commercial technologies, to the decontamination of CB agents.

4.1 Literature Search

To identify relevant U.S. and international equipment, technologies, and research and development (R&D) projects performed in the area of CB decontamination, Battelle conducted an extensive electronic literature search of several military and commercial technical databases. Based on the defined objective of this effort, Battelle, through coordination with the Chemical Warfare/Chemical and Biological Defense Information Analysis Center (CBIAC) information specialists, developed a detailed literature search strategy. The literature search was structured into several functional areas to manage the review of identified items. Over 300 keywords were developed using the CBIAC's literature search thesaurus for the following general categories:

- Skin and Personal Equipment Decontamination
- Exterior Equipment Decontamination
- Sensitive and Interior Equipment Decontamination
- Large Area Decontamination
- Decontaminants
- Specific Decontaminants
- Decontamination
- Specific Decontamination Processes
- Proactive Decontamination
- General Keywords

A detailed listing of the keywords searched for each of the above categories is provided in Appendix A. Using the keywords the following 6 databases were searched.

- Defense Technology Information Center (DTIC) Technical Report Bibliographic Database
- U.S. Army Chemical and Biological Defense Command (CBDCOM) Scientific and Technical Information Library Automation System (STILAS)
- CBIAC Bibliographic Database
- West Desert Technical Information Center (WDTIC), U.S. Army Dugway Proving Ground (DPG), Utah
- DIALOG - The Dialog Corporation
- Reuters News Service

DTIC's Technical Report (TR) Bibliographic Database represents a collection of reports describing the progress or results of research efforts and other scientific and technical information held by DTIC. The reports convey the results of Defense-sponsored research, development, test and evaluation (RDT&E) efforts. The TR databases contain nearly 2 million citations for materials such as preliminary, initial, summary, periodic, and final reports in print and nonprint (software, data files, databases and video recordings) format. This includes (but is not limited to) DoD patents and patent applications, studies and analysis reports, open source literature from foreign countries, conference proceedings, reprints, and theses. DTIC has also acquired Library of Congress Federal Research Division records that cover a variety of foreign and domestic subject areas.

The CBDCOM STILAS contains citations that correspond to the holdings in the CBDCOM Technical Library. These holdings include scientific and technical reports from current and historical RDT&E projects related to CB warfare. Reports generated by CBDCOM and all organizations previously part of the Army Chemical Command throughout the years, as well as other commands, are in this collection. Other citations contained in this database correspond to CBDCOM's vast book and serial publication holdings. Although a percentage of the holdings in the CBDCOM collection can be found in other collections such as CBIAC, DTIC, and WDTIC, there are a large number of historical documents not available at any other location.

The CBIAC Bibliographic Database (BD) is an on-line, menu-driven computerized database that provides registered users access remotely via the World Wide Web to over 53,000 citations in all CW/CBD subject areas. Of the 53,000 citations to both classified and unclassified documents, over 35,000 correspond to documents which reside at the CBIAC while the remainder are available through other collections such as the DTIC, the U.S. Army DPG, and CBDCOM.

The WDTIC database contains citations to DPG, Desert Test Center, West Desert Test Center, and DO-49 documents generated by current and historical RDT&E projects within the U.S. Army Test and Evaluation Command (TECOM). Many project test reports for a variety of chemical, biological, and munitions projects can be found in the WDTIC that are not available in any other collection.

DIALOG is a comprehensive and authoritative source of approximately 600 on-line databases. Of the roughly 600 databases, 153 of the databases are considered to be science and technology databases. Data includes the following categories: Business and Finance, Chemicals, Energy and Environment, Food and Agriculture, Intellectual Property, Government and Regulations, Medicine, News and Media, Pharmaceuticals, Reference, Technology, and Social Sciences. Market research data includes market share and sales figures, competitive intelligence, corporate finance, business directories, and financials on 14 million U.S. and international companies. The chemicals subject area includes analyses of research issues, chemical discoveries, and commercial developments. Energy and Environment tracks worldwide environmental issues, provides information for review and analysis of news, pricing, and products relating to the oil, gas, electric, and nuclear power industries and their suppliers as well as environmental topics.

One of the oldest news services, Reuters is a general news agency and a financial information distributor. The company provides real-time financial data, transaction systems, access to numerical and textual historical databases, news, graphics, still photos, and news video to the global business community and news media. The company relays news and financial information from more than 362,000 computer terminals in 161 countries.

In order to compile the information obtained from the six sources identified above, Battelle used Microsoft Access to develop a Decontamination Database. The Decontamination Database is a relational database that contains information identified from the review of the four Government owned databases (DTIC, CBDCOM, CBIAC, and Dugway). This database also contains information identified by Charles W. Williams, Incorporated in their review of the DIALOG database and the Reuters News Service. [1] In addition, this database also contains information related to decontamination equipment, technologies, and projects identified during both the literature search and the Market Survey. A snapshot of one of the screens from the Decontamination Database is shown in Figure 4.1 (page 9).

There were over 26,000 records identified in the literature search of the Government owned databases. The number of records for each of the four databases is noted in Table 4.1-1. Applicable data from the literature searches were electronically downloaded into the Decontamination Database through the use of a batch processing program. The data fields in each of these tables are unique to the particular database from which the information was retrieved. In general, the fields of information collected from each database included the abstract identification number, title, authors, publication date, report classification, abstract overview, and list of keywords or descriptors. Appendix B contains a listing of the database fields associated with the Government databases (i.e., CBDCOM, CBIAC, DTIC, and Dugway).

Table 4.1-1. Number of Records Identified By Keyword Search

Database	Records Identified
DTIC	2,547
CBDCOM	5,366
CBIAC	13,568
Dugway	4,819

In support of the literature search, relational database tables were created for the data that related to the four Government-owned databases, along with the Commercial and "Out-of-the-Box" Applications. The Commercial and "Out-of-the-Box" application tables contain all of the integrated records identified by Charles W. Williams, Incorporated during their search of the Dialog and Reuters News Service commercial databases. The Commercial applications table focuses on standard

[1] Since DIALOG and Reuters News Service are not Government owned databases all copyright laws were taken into account. Therefore, the information in the Decontamination Database from DIALOG and the Reuters News Service was integrated into major technical areas. These major technical areas are a summation of all the records that were identified during the search process related to a specific decontamination technology.

decontamination technologies and practices that are currently applied in private industry or Government agencies and may have some application to the decontamination of CB agents. The "Out-of-the-Box" applications table contains data on various "crossover" technologies that may also be applicable to the decontamination of CB agents.

In support of the Market Survey, relational database tables were developed for the technologies, equipment, and projects table. The technologies table contains a listing of the various decontamination technologies and the specific decontaminants associated with that technology. The equipment table contains all of the technical information related to the military, commercial, and industrial decontamination equipment that was identified during the Market Survey. The projects table contains a listing of the various decontamination projects that were identified while conducting both the literature search and the Market Survey.

Each record in the database was then printed and reviewed by Battelle technical personnel to determine the record's relevance to the objectives of this study. A relevancy rating scale ranging from 0 (not relevant) to 3 (highly relevant) was used. Records that rated 0 did not contain any reference to CB decontamination. Records that rated 1 contained the word "decon" in their list of keywords, but may not be technically relevant to CB decontamination. Records that rated 2 contained a reference to general decontamination in both their title and abstract overview and were also determined to have "some" relevancy to the current decontamination study. Records that rated 3 contained a reference to a specific CB decontamination technology, equipment, or project in the abstract title and abstract overview and were determined to specifically apply to the current decontamination study.

Relevant records (those receiving a relevancy rating of 1, 2, or 3) were then categorized into one or more of the following five functional areas:

- Skin and Personal Equipment Decontamination
- Exterior Equipment Decontamination
- Sensitive Equipment Decontamination
- Interior Equipment Decontamination
- Large Area Decontamination

A Battelle senior scientist then reviewed each record receiving a relevancy rating of 1, 2, or 3. The objective of this second review was to more specifically identify the most applicable documents for each CB decontamination functional area. Selected documents were then ordered from the respective databases. Irrelevant records (those receiving a relevancy rating of 0) were removed from the Decontamination Database.

Using the populated Decontamination Database, searches were conducted to identify and sort the information contained within the database into specific CB decontamination technologies, equipment, and projects. The sorted information was then analyzed and summarized by Battelle technical personnel and used in the development of this report.

4.2 Market Survey

To further identify relevant U.S. and international equipment, technologies, and R&D projects in the area of CB decontamination that may not have been adequately covered or identified by the Literature Search discussed in Section 4.1, Battelle conducted a detailed Market Survey. The Market

Survey was divided into two elements: military (U.S. and international) equipment manufacturer's and commercial/industrial sources. All information acquired through the Market Survey was incorporated into the Decontamination Database and then used to support the development of this report.

4.2.1 U.S. and International Military Market Survey. For the U.S. and international military Market Survey, Battelle reviewed Jane's NBC Defence Systems publications and identified CB decontamination equipment from over 25 different countries. For the CB decontamination equipment identified, the equipment name, manufacturer, and system capabilities were entered into a separate element of the Decontamination Database discussed in Section 3.4. Each of the vendors identified through the Jane's publications were then directly contacted via facsimile and/or e-mail to acquire additional information on the equipment identified.

To augment the international military Market Survey above, North Atlantic Treaty Organization (NATO) members Canada, France, Germany, the Netherlands, and Italy were contacted directly through facsimile and/or electronic mail and requested to provide a listing of any current equipment, development projects, and points of contact involved in the development of current or new decontamination technologies within their respective countries. Table 4.2-1 identifies the contacted NATO member organization points of contact.

Table 4.2-1. NATO Members Contacted

Country	Point of Contact
Canada	Dr. J. Garfield Purdon, Defence Research Establishment Suffield
France	Mr. Gilbert Magnaud, CEB
Germany	Dr. Alexander Grabowski, WIS ABC-Schutz
Netherlands	Mr. Simon C. Van Switen, PML-TNO

Battelle also conducted a detailed Internet search using Metacrawler for international military home pages. Metacrawler is an Internet search engine that combines all the main search engines (e.g., Lycos, Excite, Infoseek, Yahoo) into a single search. Identified international military home pages were accessed and reviewed for relevant CB decontamination information or additional points of contact. Appendix C identifies each of the military home pages identified, accessed, and reviewed. Through the Internet, Battelle also searched for contact information for companies/institutes that attended the CBW Protection '98 Conference in Stockholm, Sweden, as well as information collected by Battelle representatives attending the conference.

4.2.2 Commercial/Industrial Source Market Survey

For commercial/industrial sources of CB decontamination technologies and equipment, Battelle relied upon the Thomas Register of American Manufacturers. Using the keywords: decontamination, decontamination equipment, decontamination services, decontamination procedures; 80 companies were identified, and those offering relevant products are listed in Appendix C. Battelle then conducted a detailed Internet search using Metacrawler to identify any relevant commercial/industrial home pages. Identified commercial/industrial military home pages were accessed and reviewed for relevant CB decontamination information or additional points of contact. Appendix C identifies each of the commercial/industrial home pages identified, accessed, and reviewed. If relevant information was identified, the commercial/industrial vendor was directly contacted and relevant information was requested. All information acquired through this process was incorporated into the Decontamination Database.

Battelle employed the use of a subject matter expert (SME) to survey the commercial/industrial Asian market for relevant CB decontamination technologies and equipment. The SME, relying on personal contacts within the region, identified and contacted various officials and commercial organizations working in the chemical industry. The SME stated that most of the officials and company representatives he contacted were inquisitive about why he was asking for information related to their decontamination equipment and technologies and requested that he provide a written request for the information. Approximately 50 facsimilies were sent to the various officials and company representatives. However, no information has been provided by any of the officials or companies contacted. The organizations contacted are listed in Appendix D.

4.3 "Out-of-the-Box" Study

The "Out-of-the-Box" study focused on identifying through non-traditional search strategies, potential "crossover" technologies used in other applications that may be applicable for use in CB decontamination. Using the DIALOG and Reuters News Service commercial databases, potential crossover technologies were identified and assessed. The results were then formulated into potential integration concepts and presented.

The performance of an "Out-of-the-Box" analysis comes from a relatively "free form" analysis of comprehensive data inputs developed from a paradigm independent of and external to the traditional type of activities and technical disciplines for which the "crossovers" are intended. In this sense, the results are a blend of an art form, judgment honed by non-specialized experiences across a wide range of subjects and analytical techniques designed to support this type of assessment. For the performance of this type of assessment, Battelle employed Charles W. Williams Inc.

Charles W. Williams Inc. is a small firm specializing in development of customized trend analysis, business, and technical intelligence. The firm has been in operation since 1972. Their focus is on providing customized finished intelligence to clients so they can take advantage of, rather than be confounded by, the emerging changes in their business environments. Past consulting assignments have included strategic assessments on a global, regional, and national scale. Their client list includes General Foods, Kraft Foods, Johnson & Johnson, Monsanto, Union Carbide, Praxair Industrial Gases, James River Paper, Battelle, the National Science Foundation, the U.S. Coast Guard, the U.S. Department of Agriculture, and agencies in the U.S. National Security Community. Prior to establishing his independent practice, the principal (Mr. Williams) served in a variety of U.S. Government posts in the Department of Defense, the U.S. National Science Foundation, White House staff, and the Stanford Research Institute.

The "Out-of-the-Box" study was initiated with the development of illustrative profiles identifying the types of industrial situations in which some sort of decontamination was conducted. An operational definition was then defined that outlined the characteristics of the military targets to which the analysis would be directed. This was followed by the development of a detailed set of criteria to evaluate the potential ideas. With the above defined as the analysis basis, a detailed search of the DIALOG and Reuters News Service electronic databases was initiated.

Using the assumption that report authors would define what industries considered to be conditions of contamination and or decontamination, an initial sample of documents were extracted from

DIALOG and Reuters News Service using the keywords "decontaminant" and "contaminate". From this initial search it was determined that industry does not consider decontamination to be a technology. The term is highly skewed to define techniques related to nuclear clean up, waste management, and blood quality. From these results, the search strategy was altered and several variations tested to provide a more comprehensive and representative baseline of data for the purpose of analysis. After this initial analysis, a customized code was developed to classify the information to be collected and to develop a conceptual framework for the overall analysis and assessment.

Select areas of DIALOG and Reuters News Service were then searched with the revised search strategy of keywords and classification coding. All data collected was converted to a common database format to facilitate an integrative analysis. The data was then coded with the customized structure. All documents given a common code were assembled into sets and synthesized as a series of discreet "cells" of information. Throughout this collection process, ideas for crossover were generated as the insights occurred. The integrated summaries across codes were then analyzed and a table of potential crossover ideas was developed. Each of these ideas was then expanded upon by a set of crossover concepts.

The final step of the analysis relied upon creative thinking by the technical reviewers to carry the individual crossover concepts to a higher level of synthesis with the intended military applications. Here the various concepts developed were combined into "integrated systems" of potential decontamination technologies and applications. Section 8 of this report provides a complete discussion of the results of the "Out-of-the-Box" study.

4.4 Summary Assessment

At the conclusion of the three efforts discussed above (Literature Search, Market Survey, and the "Out-of-the-Box" Study), Battelle performed a detailed assessment of all the results identified. The objective of the summary assessment was to assess the technologies and equipment identified to determine those that offered the most promise for meeting the immediate needs of the CB Wide Area Decontamination Program. The summary assessment also included a detailed examination of the potential use of combining the technologies and equipment identified into hardware solutions for immediate implementation.

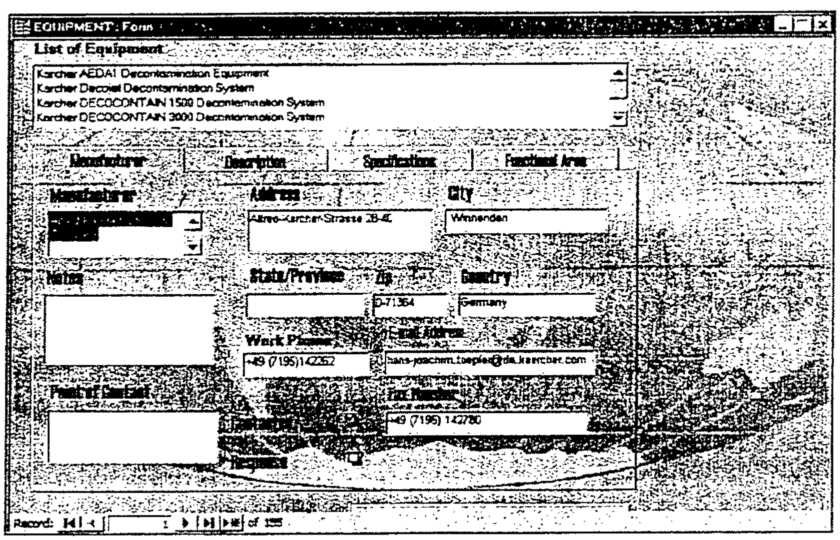


Figure 4.1 Snapshot of the Decontamination Database

5.0 CB Decontamination Technologies

Over the years, numerous technologies have been studied to determine their applicability to improving the effectiveness of the CB decontamination process while minimizing the effects on human health, equipment, and the environment. While much work has been conducted in the area of chemical decontamination, only recently has a strong emphasis been placed on identifying effective biological decontaminants. Many of the decontamination technologies identified in this section, although heavily researched for their chemical decontamination effectiveness, may also be effective against biological warfare agents. These solutions include bleach, sodium hypochlorite, formaldehyde, and phenol, which are effective for decontaminating contaminated surfaces and equipment. These chemicals are also effective against anthrax spores on contaminated surfaces. However, anthrax spores, which contaminate soil or vegetation, are nearly impossible to decontaminate. Many biological agents are susceptible to heat (burning/incineration), ultraviolet radiation, and gamma radiation. Where applicable, the potential biological decontamination properties of the decontamination technology being reviewed are discussed. Unfortunately, much of the current research in this area is currently being performed with the results not yet published in an accessible forum.

This section provides an overview of technologies that have been, or are currently being considered for implementation. The discussion provided is intended to provide the reader with an understanding of the basic tenets of each technology, identify several current applications, identify any related evaluation efforts, and provide a basic assessment of each technology's potential for meeting the needs of the CB Decontamination Program. The details on current equipment and projects associated with each technology can be found in sections Section 6.0 and 7.0. Discussions on potential novel technologies from commercial applications can be found in Section 8.0 under the "Out-of-the-Box" study results. Section 9 details the results of the assessment of all the technologies and equipment identified to determine those that offer the most promise for meeting the immediate needs of the CB Decontamination Program. The summary assessment includes a detailed examination of the potential use of combining the technologies and equipment identified into hardware solutions for immediate implementation.

5.1 Coatings and Paints

Coatings, including paints, are employed on military vehicles and other equipment to protect them from the environment (oxidation) and to camouflage them from the enemy. Chemical agents and some of the decontaminants are chemicals that can readily be absorbed by these surface application coatings. Sorption by a coating may produce a long-term vapor hazard due to the released vapors of the chemical agents from the surface of the coating. Therefore, it is important to eliminate or significantly reduce the sorption of chemical agents into the coating since once sorbed into the coating the agent is not easily decontaminated and may pose a longer term vapor hazard to personnel.

The decontamination of coated surfaces can damage the coatings because of the reactive and caustic nature of some of the common decontaminants. For example, DS2 contains organic solvents and is highly caustic. Left on surfaces for an extended period, it often damages the surfaces to the point of requiring repair. Because of this corrosive nature the contact time for DS2 on vehicle surfaces is limited to 30 minutes followed by a water wash. Other decontaminants, such as strong oxidizers (e.g., bleach) can also harm many coatings due to the solution's high degree of corrosivity. New coating systems are being investigated to reduce or eliminate the problems associated with agent absorption and degradation of the coating during decontamination. Three such coating systems are chemical agent resistant coatings (CARC), sacrificial coatings, and self-decontaminating coatings.

CARCs are polyurethane-based coatings designed to be chemically resistant to both chemical agents and decontaminants. When a chemical agent is deposited onto the surface of a CARC coating, the

CARC surface repels the agent causing it to form droplets on the surface. These agent droplets can then be readily decontaminated through existing decontamination procedures.

The intent of sacrificial coatings is to quickly absorb deposited chemical agents to reduce vapor hazards. Once the agent is absorbed into the sacrificial coating, the now contaminated coating can either auto-release from a non-contaminated substrate under the sacrificial coating or it can be stripped off using relatively mild decontaminants such as hot soapy water.

The concept of self-decontaminating coatings is to develop a coating that contains reactive sites, such as catalysts, that have been "designed" to decontaminate chemical and biological warfare agents on contact. The goal is to provide an immediate means of decontaminating CB agents from surfaces as soon as the agent makes contact with the self-decontaminating coating.

5.1.1 Current Applications

The use of CARCs is a proven technology and is widely applied to many military applications. Most military vehicles (e.g., M1A1, M2A3) and varying equipment (e.g. CB equipment) are coated with a polyurethane-based CARC paint to protect them and facilitate decontamination efforts. The application of sacrificial coatings has been limited due to the less than satisfactory performance of the coating developed to date. The application of self-decontaminating coatings is also limited due to its current state of research.

Protective coatings and paints are also used extensively for commercial applications. New chemical resistant coatings are available for industrial and institutional uses. PolySpec® Corporation, located in Houston, Texas, manufactures NovoRez® coatings, which are a new line of chemical resistant coatings. These coatings are designed to protect concrete and steel structures in chemical processing plants and secondary containment from chemical contamination. The NovoRez® 360 can resist methylene chloride, acetic acid, and dilute phenol without postheat curing, while the NovoRez® 351 has become an industry standard for concentrated sulfuric acid service. Dow Corning®, located in Midland, Michigan, also manufactures protective silicone coatings for sensitive equipment (i.e. electronics, tools). The coatings are designed to protect parts from high humidity, corrosion, and salty conditions. These coatings could potentially be used to protect sensitive equipment from chemical and biological agent contamination. Chemsol, Incorporated, located in Farming Hills, MI, also manufactures a wide variety of paints and coatings.

5.1.2 Evaluation Results

Several evaluation efforts were identified for CARCs, sacrificial, and self-decontaminating coatings through the CBIAC database. Acrylic and polyurethane coatings were formulated with the incorporation of reactive ion exchange resins (RIER). The insertion of RIER in the coatings was expected to aid in the catalytic decomposition of chemical agents on the coating surface. Evaluations of the formulations with the simulant diisopropyl fluorophosphate (DFP) indicated that the inclusion of RIER in the formulations enhanced the chemical agent resistant capacity of the coatings (CBIAC AD-D750249).

A polyurethane CARC and a chemically strippable coating were studied in an effort to enhance the chemical agent resistance of these coatings by the addition of decontamination capabilities to the coatings. The enhanced decontamination capabilities were expected to originate from the addition of particles to the coatings that sorb and catalytically degrade the chemical agent. Results obtained demonstrated the feasibility of formulating successful coatings with sorptive/catalytic particles (CBIAC AD-B126381).

The application of parylene conformal coating technology was studied as an alternative means for protecting material from chemical agents and the effects of decontamination. Several commonly used conformal coatings were exposed to DS2 to test their resistance to decontamination procedures. Only the parylene family of polymers proved to be immune to the agent (CBIAC AD-D751331).

The decontamination efficacy of two sacrificial coatings was evaluated. The coatings consisted of a recent formulation (optimized coating) and its precursor, Pentek 620. Efficacy was judged by chemical agent removal from bare metal panels and by the reduction of the vapor hazard. Sufficient decontamination data were obtained to suggest that the coatings absorbed significant amounts of the agent. Absorbed VX seemed to be tightly held in the coatings. The optimized coating did not significantly reduce the vapor hazard above thiodiglycol (TDG) and was not significantly better than evaporation for removal of GD. The Pentek 620 coating was effective in reducing the GD vapor hazard, but this apparent advantage is probably due to the poor auto-release properties demonstrated by the coating under the test conditions used. None of the coatings auto-released from the test panels coated with CARC (CBIAC AD-B145448).

5.1.3 Technical Assessment

Chemically resistant coatings are based on the assumption that a polymeric material can be designed that exhibits little affinity for chemical agents and most decontaminants. From a chemical perspective, the solubility of both the chemical agents and the decontaminants need to be minimized in the coating. This is not a trivial matter in that the chemical agents range from slightly to highly soluble in water and common decontaminants range from fully aqueous systems containing reactive species such as bleaches to fully non-aqueous systems such as DS2 that contain organic solvents and strong bases. However, designing coatings to be non-absorptive to chemical agents allows for the use of less corrosive decontaminants.

The addition of reactive and/or catalytic species into the coatings is an attempt to minimize the amount of decontaminant needed. Through self-decontamination, surfaces can be washed with soap and water since only the products of decontamination need to be removed. However the reactivity of the species is significantly reduced when added to a coating. This is primarily due to the decrease in surface area of the reactive species. For this reason the incorporation of a reactive species into polymeric coatings by formulating mixtures is probably not the best way to approach the problem. It may be more feasible to first apply a polymeric coating that contains reactive sites on the polymeric backbone. Once applied the coating can be exposed to a reagent (possibly enzymatic) that will chemically attach to the coating. The reagent will attach only in places where it can make contact, thereby maximizing the reactive coverage of the coating. By chemically binding the reagent to the coating surface, the surface chemistry of the coating is altered to be highly reactive to chemical agents. This approach maximizes the reactive surface area of the coating and takes advantage of the current state-of-the-art in surface modification to obtain the desire chemical properties.

5.2 Electrochemical

This technology deals with the application of electrical energy to a pure chemical or a chemical in a solvent causing the chemical to be oxidized or reduced. In an electrical system where two electrodes are placed into a solution and connected to a battery, the electrode attached to the positive battery terminal is called the anode and the electrode attached to the negative terminal is called the cathode. When both electrodes are attached to the battery and current flows through the solution, oxidation of the chemical occurs at the anode and reduction takes place at the cathode. In general, compounds can be readily oxidized or reduced in solution as long as the solvent is not oxidized or reduced first. For example, if sodium chloride is placed into water and a large potential is placed across two electrodes in the water, hydrogen is evolved at the cathode and chlorine evolved at the anode. Sodium is not produced from aqueous sodium chloride because the water is more easily reduced than sodium and, therefore, hydrogen is preferentially produced. However, in a sodium chloride melt when a potential is applied chlorine is produced at the anode and sodium metal produced at the cathode. It should be noted that while chemical agents may not be directly oxidized or reduced using electrochemistry, electrolysis of water containing sodium chloride produces large amounts of the hydroxyl ion (OH^-) which will cause base hydrolysis of agents such as GB.

5.2.1 Current Applications

Systems for cleaning soils by application of an electrical potential between two electrodes placed into the soil are currently being marketed. Wells are first drilled and perforated plastic pipes placed into the holes. Electrodes are placed into each well, the soil is soaked with water, and a low voltage DC current is passed through the soil. Pollutants are loosened and moved to the electrodes by electrical, chemical, and hydraulic forces in the soil. The pollutants are drawn into the wells containing the electrodes and pumped from the wells for safe disposal.

5.2.2 Evaluation Results

Electrochemical decontamination of soils can be done on all clay soils and most soils containing >50% silt and or clay. The system can be placed into the ground and operational in a very short time depending on the volume and geometry of the soil mass to be decontaminated. In general soil decontamination can be accomplished in 4 to 8 weeks. Between 75% to 90% of heavy metals are removed from the soil and 90 to 99% of the organic contamination are removed.

5.2.3 Technical Assessment

Electrochemical decontamination of chemical agents in soil may be possible with the system described above. However, based on work by Kingery, et al (A.F. Kingery, H.E. Allen, "Environmental Fate of Alkyl Methylphosphonates Arising from Chemical Surety Material (CSM) and Potential Non-CSM Sources in Soil and Aqueous Media", U.S. Army Environmental Center, Contract #DAAL03-86-D-0001) the agents GB and VX decompose rapidly to low toxicity products in a manner of a few days. For example, when 14 mg/L of GB is placed on soil, it degrades rapidly to the corresponding phosphonic acid. It can be expected that VX and to a lesser extent HD will do the same. Therefore, the need for electrochemical decontamination of soils is probably low for GB contamination, low to medium for VX contamination, and medium for HD contamination. This being said, electrochemical decontamination of soils contaminated with the environmental breakdown products of chemical agents may have an application for wide area decontamination during the remediation portion of the effort.

5.3 High Pressure (Supercritical Fluids)

The term "supercritical" defines the state of any fluid that has been heated and compressed above its critical point, which is defined by both temperature and pressure. Fluids in the supercritical regime possess unique properties that make them highly suitable as cleaning and extraction solvents, given that they have densities, which approach those of the liquid phase while maintaining viscosities, and mass transport properties that approach the gas phase. A supercritical fluid can best be described as a "dense gas", being neither a liquid nor a gas while retaining some of the unique properties of both. Additionally, supercritical fluids are highly tunable solvents where small changes in either temperature or pressure can effect significant changes in that fluid's ability to solubilize other compounds. This unique property can be used to effectively dissolve into, and/or selectively disengage solute materials from, the bulk solvent stream resulting in highly efficient separation operations.

The critical point for any compound is defined in a manner similar to the compounds triple point. The triple point defines a temperature and pressure where all three states of matter exist at once, while the critical point defines a temperature (T_C) and pressure (P_C) where any increase in either will not force that substance into either the solid, liquid, or gas phase. The behavior of the unique properties (i.e. density and dielectric strength) of fluids as conditions change in the supercritical region is not consistent for different fluids. Therefore, the effectiveness and behavior of a particular fluid should not be related to the performance of another fluid. The supercritical fluids identified in this effort are water and carbon dioxide. Water (T_C = 374.4°C, P_C = 219.5 atm) and carbon dioxide (T_C = 31.0°C, P_C = 73.0 atm) behave differently in the supercritical region and are being evaluated for different decontamination purposes.

Supercritical fluids are currently being investigated for chemical agent decontamination on two separate levels. One is to investigate the use of supercritical fluids as a reaction medium for the destruction of toxic chemicals, and secondly as an extractive/cleaning solvent for the removal, and subsequent collection/isolation, of toxic chemicals from equipment that current neutralizing solvents would otherwise damage. The ability to control the solvation of targeted compounds allows for more efficient and cost effective separation of the products from the resulting solution. In addition to the unique physical properties displayed by supercritical fluids the two fluids, being investigated for chemical agent decontamination, carbon dioxide and water, are environmentally safe. Neither of these supercritical fluids would produce large amounts of hazardous chemical waste.

5.3.1 Supercritical Carbon Dioxide

Supercritical Carbon Dioxide ($SCCO_2$) is the result of gaseous carbon dioxide (CO_2) being compressed to its critical pressure of 72.9 atmospheres (atm) and heated to its critical temperature of 31°C. Because of the unique physical conditions associated with the supercritical phase, the solubilization properties of CO_2 are greatly enhanced in this state. $SCCO_2$ has similar solvent properties to that of methylene chloride (dichloromethane). The addition of small amounts of chemicals such as alcohols or hydrocarbon solvents can also improve the solubilization powers of $SCCO_2$, allowing for its use in situations never considered before.

$SCCO_2$ is well suited for the decontamination of sensitive equipment such as optics, sensitive gauges, inertial guidance and navigation equipment, and other types of electronic devices that would be damaged or destroyed by the use of strong oxidants or bases. While $SCCO_2$ will not detoxify the chemical agent contaminating the equipment, it will solubilize and remove it from the equipment. The $SCCO_2$ will contain the agent and need to be detoxified by directing it through a charcoal filter, reactive polymeric resin, or through a conventional decontamination/detoxification solution. By passing the waste $SCCO_2$ through a filtration system the user has the ability to purify and recycle the CO_2 for repeated usage. Recycling CO_2 will reduce the costs and physical size of any equipment associated with $SCCO_2$ cleaning.

Because of the demonstrated ability of $SCCO_2$ to extract organophosphorous pesticides, including parathion, which has been used as a chemical agent simulant, from a variety of sample matrices, it has been concluded that $SCCO_2$ would be effective in the removal of G agents, VX, and HD.

5.3.1.1 Current Applications. Industry has employed $SCCO_2$ in two different ways. The more common use of $SCCO_2$ is as an extraction device. The second major industrial use is as a cleaning agent. Development projects involving the use of $SCCO_2$ to clean intricate or delicate equipment and as a replacement solvent for the dry cleaning industry are currently in progress.

As an extraction device, $SCCO_2$ is inexpensive and in many cases reduces the number of steps required for extraction. In a laboratory or analytical setting, $SCCO_2$ extraction is non-polluting and non-toxic as opposed to organic solvent usage. $SCCO_2$ is employed as a solvent in the preparation of soils or solid wastes for analysis of environmentally significant compounds by gas and liquid. Another laboratory use for $SCCO_2$ extraction has been in the analysis of animal tissues for the removal of the aflatoxin M1. $SCCO_2$ extraction is not solely used in the laboratory. In recent years, $SCCO_2$ has begun to be used in the extraction of caffeine from coffee beans.

For decades, industry has employed solvents as cleaners of all varieties of equipment. Many of the solvents currently employed by industry are chlorinated solvents that contain Freon, which are now being eliminated by environmental regulations. Companies such as CF Technologies, Painter Design & Engineering, and EnviroPro Technologies have developed parts cleaning equipment that employ $SCCO_2$ as the cleaning solvent. Southwest Research Institute and Air Force researchers at Wright Patterson Air Force base developed a process for cleaning small equipment employing $SCCO_2$. $SCCO_2$ was able to remove oils, greases, and waxes from weapon systems while minimizing the waste stream and eliminating hazardous wastes. The Department of Energy (Office of Industrial Technologies) along with Los Alamos National Laboratory, Sandia National Laboratory, and Pacific Northwest National Laboratory has been working to apply $SCCO_2$ technology for precision cleaning, cleaning printed wire boards, electronic components, and dry cleaning in particular and sold 22 units in 1995.

To date, the $SCCO_2$ has proven effective in penetrating small openings and cleaning precise equipment. To enhance the cleaning capabilities of $SCCO_2$: agitation, surfactants, cosolvents, reverse micelles and microemulsions, and ultrasonic cleaning can be employed. As opposed to other supercritical fluids, $SCCO_2$ is desirable because of its relatively low temperature and pressure that is required to initiate the supercritical state.

5.3.1.2 Evaluation Results. Documentation detailing the results of testing of $SCCO_2$ is limited. For the purposes of this survey, interest in testing related to the ability of $SCCO_2$ to remove chemical agents, biological agents, standard greases and oils and the impact of $SCCO_2$ on the variety of materials it may be used to decontaminate are of importance.

The U.S Army Edgewood Chemical Biological Center (ECBC) is currently investigating the use of $SCCO_2$ for chemical agent decontamination of sensitive equipment. To date ECBC has employed a bench top $SCCO_2$ cleaning system to perform testing with HD and are starting tests on VX. Although no results from these tests have been published, initial indications are that $SCCO_2$ was able to successfully remove HD on a laboratory scale. Testing performed between 1982 and 1984 on chemical agent simulants (DMMP, DEP, TDE, and TBP) were summarized in a "Supercritical Fluid Decontamination and Cleaning Applied to U.S. Army Needs Volumes I and II" (AD-B078480 and AD-B090867). These tests revealed that $SCCO_2$ was effective on the DMMP from contaminated activated carbon linings of protective garments. Additional results from this testing show that $SCCO_2$ is effective in cleaning grease, sweat, and oils from combat boots, load-carrying gear, rubber protective masks, and protective garments with activated carbon linings.

Battelle performed testing on the effect of $SCCO_2$ on aircraft bearings performed between September 1993 and January 1994. The report "Testing and Evaluation of Supercritical Dioxide Cleaning Technology as Applied to Aircraft Bearings and Aircraft Instrument Bearings" by Bruce M. Sass summarizes the results of that testing. The results revealed no significant length or weight changes on Teflon™, Delrin™, Phemolic™, and Meldin™ bearings as a result of $SCCO_2$ cleaning.

The University of Massachusetts Polymeric Science Plastics Engineering Program, in conjunction with Los Alamos National Laboratory, has done material compatibility testing for $SCCO_2$ and a variety of polymers. These tests revealed several materials that were not very compatible. The results of this testing are summarized in a book titled "Evaluation of the Interactions Between Supercritical Carbon Dioxide and Polymeric Materials" by Samuel P. Sawan, Yeong-Tarng Shieh, and Jan-Hon Su.

Internet sources reveal that other testing has been done that reveals positive results for the implementation of $SCCO_2$ for military cleaning purposes. Los Alamos National Laboratory tested material including: aluminum, glass, copper, brass, stainless steel, and epoxy boards and found that the substance being cleaned had more of an impact on the cleaning efficiency than the material being cleaned and that $SCCO_2$ is a viable candidate to clean water sensitive or temperature sensitive parts and precision parts.

5.3.1.3 Technical Assessment. Because $SCCO_2$ cleaning requires that equipment to be cleaned be placed in a controlled reactor, the potential for $SCCO_2$ cleaning should be focused on its ability to clean sensitive equipment and smaller sized personal equipment. There is a multitude of advantages to employing $SCCO_2$ for this use: focusing mainly on the low cost of CO_2, limited environmental impact, and the cleaning characteristics of CO_2 in the supercritical state.

The ability of $SCCO_2$ to clean chemical agents must still be proven, and a verified list of what equipment can or can not be cleaned in the supercritical environment needs to be generated. There will be issues regarding equipment that contain polymers and any equipment that might be hermetically sealed. Additionally the $SCCO_2$ process needs to be optimized to perform as efficiently as possible. However, given the available information, it appears as though $SCCO_2$ cleaning is a viable option for cleaning the sensitive equipment and smaller personal equipment handled by U.S. military personnel.

5.3.2 Supercritical Water Oxidation (SCWO)

A supercritical fluid can be considered to be somewhere in between the physical states of gaseous and liquid. Because of this unique physical condition, the solubilization and reactive properties of water are greatly enhanced. Both industry and the U.S. Army are investigating the use of SCWO to destroy wastes. SCWO is mainly being investigated as a means of transforming toxic wastewater and organic sludge to non-hazardous by-products as a replacement for incineration. The common resultant by-products of SCWO are water, carbon dioxide, and ash. The addition of gaseous oxygen (an oxidant) to supercritical water to detoxify chemical agents has been investigated.

5.3.2.1 Current Applications. The implementation of SCWO technology as a replacement for incineration is in initial stages. The University of Texas and Eco Waste Technologies (EWT) have proved to be leaders in this process.

The University of Texas (UT) performs research on the capabilities of SCWO to destroy wastes in laboratory reactors, the largest of which can treat 40 gallons of waste per hour. UT has also participated in studies concerning the development of a mobile SCWO unit for the U.S. Military.

EWT designed the first commercial SCWO waste process facility for Huntsman Corporation. The Huntsman SCWO facility was built in Austin, TX and handles approximately 300 gallons of waste per hour and has been in operation since the spring of 1994. EWT is teamed with Shanko Pantec Co. Ltd. of Japan and with Chematur Engineering of Sweden to develop SCWO facilities in those countries.

5.3.2.2 Evaluation Results. Information regarding laboratory scale testing of SCWO technology and its effectiveness in dealing with chemical agents and chemicals with properties similar to chemical agents is available in a series of reports. A main sponsor for the work performed in this area is the U.S. Army Product Manager for Alternate Technology & Approaches. The U.S. Army Environmental Center (USAEC) sponsored a Literature Search to investigate whether SCWO would be a technology viable for use in the treatment of explosives, chlorinated hydrocarbons, and metals in soils, water, and waste sludge. No documents related to testing for this purpose were identified in this effort.

VX and GB were successfully destroyed (>99.99999%) using a bench scale SCWO continuous flow reactor. Experiments were run at temperatures of 450°C – 550°C and a pressure of approximately 4000 psi. HD was pretreated by hydrolysis due to its low solubility and successfully destroyed (>99.9999%) using the supercritical water oxidation flow reactor (AD-D755615 and AD-E479899).

SCWO has been evaluated for the destruction of chemical agents. Tests on chemicals having similar structures to agents GB, HD, and VX indicate destruction of up to 99.9999% of the surrogate compounds. Higher decontamination efficiencies can be obtained by increasing reactor residence time and/or increasing reactor temperature. It was demonstrated that settled solids are responsible for crevice corrosion, which is one of the major sources of corrosion in SCWO systems (AD-B142494 and AD-B207496).

SCWO has been investigated for the destruction of hazardous compounds such as nitrotoluene, dinitrotoluene, benzyl sulfide, and the chemical agent BZ. Zinc chloride was added to the supercritical water as a catalyst to decontaminate the BZ. Products for the decontamination of nitrotoluene were primarily char and tar (most likely as a result of the increased temperature) but when ammonia and/or dihydroanthracene were added char and tar formation was reduced and aniline and toluidine were the major products (AD-A316446).

Destruction of the chemical agent simulants dimethyl methylphosphonate (DMMP) and thiodiglycol (TDG) were carried out in a SCWO reactor at 425°C, 450°C, and 500° C. Initial concentrations of DMMP and TDG were 11,450 mg/L and 12,220 mg/L, respectively. Residence times were 1, 2, 3, 6, and 8 minutes. Test runs were done both without oxygen and with oxygen at 200% stoichiometric (AD-A254934).

A transpiring wall SCWO reactor has been designed and a ¼ scale model built for testing. The transpiring wall reactor promises to mitigate problems of salt deposition and corrosion associated with SCWO by forming a protective boundary layer of pure supercritical water (AD-D754793).

5.3.2.3 Technical Assessment. SCWO technology has proven to be effective in destroying both chemical agents and their simulants. The main issue concerning whether SCWO is a potential fit for the CB decontamination is the role it would play. Because of the extremely high pressure and temperature required to create the SCWO environment, it is not feasible for any equipment to be cleaned using this technology and retain its usefulness. However, as a means of treating contaminated water, decontamination solutions, or other hazardous materials, a portable SCWO unit could prove to be beneficial.

5.4 Low-Temperature Thermal (Accelerated Weathering)

The objective of the use of low-temperature thermal technology (i.e., hot air decontamination vis-à-vis incineration or thermal roasting) is to physically remove chemical agents from equipment through vaporization. Once vaporized, the agent is carried away from the equipment being decontaminated by airflow. The effectiveness of hot air decontamination varies with respect to the physical properties of the agent being decontaminated. For example, neat agent distributed over a non-porous surface is readily removed using heat. However, if the agent is distributed over a porous or absorbent surface it will require additional heat and time to fully remove it. Furthermore, thickened chemical agents will require more heat and time than the neat agents do. Hot air decontamination does not detoxify the chemical agent, but merely removes it from the surface of the material being decontaminated.

5.4.1 Current Applications

Hot air decontamination of chemical agents has been investigated using the exhaust of various aircraft engines to self-decontaminate the vehicle, by mounting a turbine engine to a mobile platform that can traverse around a vehicle, and by small heating units designed for decontamination of interiors. Alfred Karcher GmbH & Company of Germany manufactures several pieces of decontamination equipment that use hot air technology to decontaminate personal equipment and exterior equipment. The Karcher Hot Air Generator FB 20 is designed for the decontamination of clothing and other personal equipment placed inside a chamber or tent. The larger scale unit, the Karcher Hot Air Generator FB 60 E, is used to decontaminate vehicles, aircraft, vessels, and personal equipment. Aerostar of Romania manufactures the ADTT–1 Jet Decontamination Truck that uses a jet engine exhaust mixed with decontaminate solutions to decontaminate exterior equipment. The system can also be used for a variety of different applications including snow removal from runways, aircraft de-icing, and dousing flames.

5.4.2 Available Evaluation Results

A C-141 cargo aircraft was contaminated with the simulant diethyl malonate (DEM) as a vapor in the cargo bay. The aircraft was decontaminated using hot air delivered by the USAF AM32A-60 start carts exhaust (CBIAC AD-B220065).

C-130 and C-141 aircraft interiors were contaminated with the simulant methyl salicylate (MeS) in an attempt to compare hot air decontamination to decontamination by natural weathering in a desert environment. Two Tioga heaters were used to deliver hot air to the aircraft interior (C-130) for decontamination at Hill AFB, Utah under severe winter conditions. Weathering decontamination was conducted at Davis-Monthan AFB, Tucson, AZ for both the C-130 and C-141. It was determined that forced hot air produced considerably quicker decontamination than weathering (CBIAC AD-B225370).

The efficiency of forced hot air to decontaminate interior surfaces of combat vehicles was examined. Thickened simulants trimethyl phosphate, dimethyl adipate, and diethyl pimelate were used to represent thickened GD, thickened HD, and thickened VX, respectively, on painted, dusty/dirty, and oil/grease treated steel surfaces as well as rubber, plastic (Kevlar), and canvas materials. Kevlar and canvas exhibited the highest removal efficiencies (<90%). It was predicted that longer exposure times and increased temperatures could improve the removal efficiencies for other surfaces (CBIAC AD-B094205).

Exhaust gas from various military vehicles was investigated to determine its usefulness for hot air decontamination. Three categories of equipment were studied: diesel engines, space heaters, and turbine engines. The diesel engine on the M35A1 truck, the Herman Nelson space heater, and the T-62 APU turbine were chosen as representative pieces of equipment from each category for testing. The heat output from each piece of equipment was determined and used to estimate the heat output from other equipment in each category (CBIAC AD-B111060).

As part of the Program Manager for Chemical Demilitarization's (PMCD) Cryofracture Program, testing was conducted to examine the potential of warm air decontamination to remove agent from surfaces of process equipment. In two separate tests involving munitions-grade HD and VX drawn from the chemical agent stockpile located at Tooele, UT, 10 μl of agent was placed in various locations on the Materiel Transfer Robot. Air, heated from 125 °F to 180 °F, was blown across the agent and the agent concentration within the test fixture was measured. Results indicated that decontamination of the surfaces was possible and was dependent upon the type of surfaces, the temperature employed, and the amount of agent involved. The time required to decontaminate the surfaces was dependent on these factors. They also found that stainless steel surfaces were decontaminated faster than plastics (PMCD DDCC A01-0421.1 and A08-0398).

Testing was conducted by PMCD on GB, VX, and HD contaminated Demilitarization Protective Ensemble (DPE) suits using warm air decontamination to determine if the vapor level could be reduced to below 3X levels. At the conclusion of testing, 185 GB-, 381 VX-, and 382 HD-contaminated DPE suits treated in the warm air decontamination chamber had successfully met the 3X criteria and were at the non-detectable level using Depot Area Air Monitoring System (DAAMS) procedures. Test data show that the actual time to decontaminate used DPE suits could be substantially less than 29 hours. For example, one batch of VX-contaminated DPE suits were decontaminated to 0.21 TWA in 2.0 hours (PMCD DDCC A01-0528.1).

5.4.3 Technical Assessment

The effectiveness of hot air decontamination is dependent on the physical state of the chemical agent as well as the properties of the surface the agent is dispersed on. If it is present as pure liquid droplets on a non-porous surface, hot air decontamination will efficiently remove the agent. However, when the agent is mixed with any other liquid, the vapor pressure decreases in proportion to the concentration of the agent in the liquid (i.e., the less agent, the lower the vapor pressure). This translates to longer decontamination times. If it is dispersed onto a porous surface then additional heat will be required to raise the temperature of the porous solid to the temperature needed to volatilize the agent. This also requires more time for decontamination. As a general rule for low-temperature thermal decontamination, the longer the time available for heating the more efficient the decontamination process becomes.

It should be noted that there is a limit as to how high a temperature can be used for the decontamination of interior and sensitive equipment. By raising the temperature, the time required for decontamination could be shortened. However, if the temperature is too high, damage to the equipment may result.

Hot air has shown promise for decontamination of surfaces. Many pieces of equipment produce hot exhaust gases and potentially can be used for decontamination efforts. In order to implement hot air decontamination as a useful technology, efforts are needed to further define the physical state of agents and the surface properties (porous, non-porous, painted, fabric, max. temperature, etc.) for many pieces of equipment.

Thermal decontamination does not destroy appreciable amounts of agent, but evaporates the agent from the surface or material being decontaminated. As a result, a significant vapor hazard could be produced during decontamination. Care should be taken in positioning the decontamination site so that the prevailing winds blow evaporated agents away from friendly troops.

5.5 Reactive Chemistry

Most of the current decontaminants used in the detoxification of chemical agents can be considered to be reactive chemicals. Reactive chemicals are ones that readily react with another chemical without the need for stirring, heating, or shaking. Often, as in the case of hydrolysis of chemical agents, or in the oxidation of the agents, the reactions occur immediately with the evolution of heat, and gases (chlorine, water vapor, HCl). Reactive compounds will also interact with metallic containers and coated surfaces to corrode the surfaces. These compounds also react with animal and vegetative tissues, resulting in damage to the tissues. Examples of common reactive chemicals are calcium hypochlorite and sodium hydroxide.

5.5.1 Oxidation

Oxidation can be defined as the loss of electron density around an atom involved in a covalent chemical bond. For example, VX is oxidized to O-ethyl methyl phosphonic acid by hypochlorous acid. Here the group attached to the phosphorus atom is changed from the sulfur, which exerts little pull on the electrons in the phosphorus – sulfur (P – S) bond, to oxygen, which exhibits greater pull on the electrons in the phosphorus – oxygen (P – O) bond. The net effect is that the electron density around the phosphorus is reduced by exchanging the sulfur with oxygen (i.e., the phosphorus is oxidized).

Common oxidants used for decontamination are bleaches that produce active chlorine. Active chlorine exists in water in equilibrium with the hypochlorite ion, $3ClO^- = 2Cl^- + ClO_3^-$. Supertropical Bleach ($Ca(OCl)_2 + CaO$) and High Test Hypochlorite ($Ca(OCl)Cl + Ca(OCl)_2$), are prepared as slurries that are a mixture of water and solid bleach powders.

Calcium Hypochlorite. Calcium hypochlorite, $Ca(OCl)_2$, is a powerful oxidizing agent, and is an active component of both STB (super tropical bleach) and HTH (high test hypochlorite). The hypochlorite ion (OCl^-) generated by an aqueous solution of $Ca(OCl)_2$ is effective in the decontamination of G agents, VX in acidic solutions, and HD. Hypochlorite ions in high pH solutions (alkaline) are not very effective in the decontamination of VX for a variety of reasons. The detoxification of HD by hypochlorite is a simple process that forms several different products. Both sulfoxide (one S - P double bond) and sulfone (two S - P double bonds) species are formed, each of which undergo elimination reactions to form monovinyl and divinyl sulfoxides and sulfones. It was found that VX reacts with OCl^- ions at low pH (acidic). However, at high pH (basic/alkaline), the solubility of VX is greatly reduced, and a greater than 10:1 ratio of active chlorine to VX is required to oxidize VX as compared to a 3:1 ratio under acidic conditions. In the detoxification of VX, the P - S bond is broken and P - O, S - O, and S = O bonds are formed. When $Ca(OCl)_2$ dissolves in water, the result is a solution that also contains hydroxide ions. The hypochlorite behaves as a catalyst in the detoxification of G agents by the hydroxide ions.

Super tropical bleach (STB). STB is a combination of a powerful oxidizers, calcium hypochlorite, $Ca(OCl)_2$, and a strong base, calcium oxide, CaO. STB is effective in the decontamination/detoxification of HD, G agents, and VX. The hypochlorite ion (OCl^-) generated by an aqueous solution of $Ca(OCl)_2$ and the hydroxide ion formed by the dissolution of CaO (which produces the OH^-) is effective in the decontamination/detoxification of G agents, VX in acidic solutions, and HD. Hypochlorite ions in high pH solutions (alkaline) are not very effective in the decontamination of VX for a variety of reasons. When dissolved in water, calcium oxide forms $Ca(OH)_2$, (calcium hydroxide).

High Test Hypochlorite (HTH). HTH is a solid powder consisting of calcium hypochlorite, $Ca(OCl)_2$ and $Ca(OCl)Cl$, and is a powerful oxidizing agent. The hypochlorite ion (OCl^-) generated by an aqueous solution of $Ca(OCl)_2$ is effective in the decontamination of G agents, VX in acidic solutions, and

HD. Hypochlorite ions in high pH solutions (alkaline) are not very effective in the decontamination/ detoxification of VX for a variety of reasons.

Other bleach systems investigated for skin and personnel decontamination are Dutch Powder ($Ca(OCl)_2$ + MgO), ASH (activated solution of hypochlorite) (0.5% $Ca(OCl)_2$ + 0.5% sodium dihydrogen phosphate + 0.05% detergent in water), and SLASH (self limiting activated solution of hypochlorite) (0.5% $Ca(OCl)_2$ + 1.0% sodium citrate + 0.2% citric acid + 0.05% detergent in water).

In addition to bleach powders, other oxidizing agents used for decontamination are peroxides, ozone, potassium permanganate, chloramine-B, and fichlor.

Chloramine-B. Chloramine-B ($C_6H_5ClNNaO_2S$), also known commercially as Neomagnol, is an oxidant that is commonly used as an antibacterial agent. For use in decontaminating/detoxifying military chemical agents, Chloramine-B is impregnated into a towelette and wetted with an aqueous solution of 5% zinc chloride ($ZnCl_2$), 45% ethanol and 50% water prior to use. Chloramine-B can be used as an antibacterial agent (i.e. like Neomycin® Ointment) and as a topical antiseptic. Chloramine-B is effective in the decontamination/detoxification of HD and VX. However, Chloramine-B is apparently not effective against the G agents, nor against some biological agents.

The detoxification of HD is a multi-step chemical process. Chloramine-B dissolves in water to form protonated Chloramine-B and free hydroxide ions. The zinc chloride maintains the pH of the environment between 5 and 6. At this point, the sulfur in the HD attacks the chlorine in the protonated Chloramine-B forming a transient chlorosulfonium ion species that reacts rapidly with the $C_6H_5SO_2NH$ anion to form a sulfimide species and with water to form sulfur mustard. For VX, it was found that VX does not react with the Chloramine-B in the towelette because the pH of the decontamination solution increases in the presence of the VX. It is believed that in actual use, the VX is physically removed from the surface by the action of wiping down the surface, and by concurrent solubilization of the VX into solution.

Fichlor. Fichlor, sodium dichloroisocyanurate ($C_3N_3O_3Cl_2Na$), is a nitrogen-chloro oxidant that is commercially available. Dichloroisocyanurate is used as sanitizing, disinfecting and bleaching agents in commercial bakeries, swimming pool sanitization, automatic dishwashing detergents and scouring cleaners. Fichlor is known to be corrosive to skin, eyes and the digestive tract. Fichlor is effective in the decontamination/detoxification of VX in aqueous solution. As the pH of an aqueous Fichlor is about 6, the rate of detoxification of GB is considered too slow to be effective. It is believed that in aqueous solution, hypochlorous acid (HClO), is the reactive species. Fichlor is dissolved in water at approximately the same rate as calcium hypochlorite, and is used similarly to calcium hypochlorite.

BX24. BX24 is a decontaminant that is currently undergoing testing as an interim replacement for DS2. BX24 is a powder that easily mixes with water, and is commercially available from Cristanini S.p.A. BX24 is a mixture of dichloroisocyanuric acid sodium salt (Fichlor), sodium carbonate, sodium metasilicate, sodium tripolyphosphate, sodium lauryl sulfate and other ingredients.

In tests using MeS as a chemical agent simulant, BX24 was found to be effective in the decontamination of the simulant. Test panels were placed in predetermined locations on various military vehicles, and the BX24 solution was applied using the decontamination gun (DCONGUN) and the XM22 high pressure washer. The only difficulty encountered in the test was an occasional clogging of the tubing inside the DCONGUN by solid decontaminant. As with Fichlor, it is expected that BX24 would be effective in the decontamination/detoxification of VX and G agents.

Chlorine Dioxide. Chlorine dioxide, ClO_2, is a powerful oxidizing agent prepared from chlorine gas and sodium chlorite. ClO_2 is effective in the rapid decontamination of VX, ineffective against the G agents, and has not been tested against H/HD. As chlorine dioxide is a gas, its solutions can emit toxic and corrosive fumes that require its use be restricted to locations with proper engineering controls. ClO_2 is unstable in light, reacts violently with organic materials, and at a 10% concentration at atmospheric pressure can be easily detonated by sunlight. It has been proposed that ClO_2 be used as the final step in the decontamination of equipment with aqueous basic solutions in order to ensure complete destruction of VX and any EA2192 that could be present in the decontamination matrix.

Chlorine Gas. Chlorine gas, Cl_2, is a very reactive gas and readily reacts with all elements except the rare gases and nitrogen. Chlorine gas has been successfully used in the large-scale decontamination of VX. 100 pound batches of VX from munitions have been dissolved in a 1.5 N hydrochloric acid solution in a 1:3 ratio (VX:acid), and chlorine is added to the solution until a green color is achieved in the solution. The reaction is rapid and very exothermic. The reactive matrix is quenched with either sodium hydroxide or sodium carbonate. Destruction efficiencies of 99.999999% have been reported. It is unknown whether chlorine gas is an effective oxidant towards the G agents and HD.

Chlorine dioxide, chlorine gas, and ozone are volatile chemicals which are examples of reactive gases that can be used to react with, and detoxify chemical weapon agents. Chemicals such as ozone or chlorine can be used to fill a confined space, react with and detoxify chemical agents. After detoxifying chemical agents, the space being detoxified can be vented and flushed with air. Reactive gases are useful for the decontamination of interior surfaces such as aircraft, office spaces, or vehicle interiors.

Potassium peroxydisulfate. Potassium peroxydisulfate, $K_2O_8S_2$, is used as an oxidizing agent. Its use in combination with a silver ion catalyst has been proposed for the decomposition of VX, but there is apparently no experimental work to report. The DOE's Lawrence Livermore National Laboratory has also proposed the use of peroxydisulfate salts for the detoxification of chemical agents and for completion of the oxidation process. It was found that at 100°C, 98 to 99 percent of agent surrogates were oxidized to carbon dioxide in 3 minutes. The use of peroxydisulfate salts, however, generates a very large waste stream of sulfate and sulfuric acid (about 30 times the weight of the agent being decontaminated).

Potassium peroxysulfate. Potassium peroxysulfate, K_2O_4S, is a component of Oxone™ . Oxone™ is a mixture of 2:1:1 (molar ratio) of $KHSO_5$:K2SO_4:$KHSO_4$. In water, the Oxone™ solution has a pH of 2.3 at 20°C and readily reacts with VX to form ethyl methylphosphonic acid (EMPA) and N,N-diisopropylaminoethanesulfonic acid (diisopropyltaurine) almost exclusively. It is noticed that EA2192 is not formed as a byproduct when Oxone™ is used as a decontaminant for VX. Oxone™ also oxidizes HD to the sulfoxide almost immediately, which is then converted into the sulfone within an hour. Unfortunately, Oxone™ cannot quickly decontaminate nor detoxify the G agents. Oxone™ will acid-catalyze the hydrolysis of the G agents, but the kinetics are extremely slow.

5.5.1.1 Current Applications. Various oxidants are currently in fielded equipment for decontamination of CB agents. Compounds such as STB and HTH are prepared in slurry form with water for decontamination of vehicle exteriors. Large pumping units, such as the M117, are used to deliver the oxidant slurry to the vehicle exterior. Dry bleach powder can also be used to decontaminate agents on surfaces. The M258A1, Decontamination Kit, Personal, and the M280, Decontamination Kit, Individual Equipment both use chloramine-B which destroys both HD and VX via an oxidation reaction.

5.5.1.2 Evaluation Results. Dicholoroisocyanurate (Fichlor) was used to decontaminate VX with the goal of decontaminating M55 VX rocket munitions. It was observed that a solution containing 0.15M Fichlor at a pH of 6.0 to 6.5 was effective for the decontamination of VX (CBIAC AD-B063894).

Oxidants and surfactants were studied to determine their suitability in a chemical agent decontamination formulation. Fichlor (sodium dichloroisocyanurate) in combination with the water soluble shipboard deck cleaner was recommended for chemical agent testing (CBIAC AD-D750570).

Decontaminating Agent: Multipurpose (DAM), a microemulsion system that contains Fichlor (sodium dichloroisocyanurate) as the decontaminating agent, was tested for decontamination of VX, THD, HD, and TGD on polyurethane (CARC) painted panels. The DAM solution was compared to DS2 and German C8 for decontamination efficacy (CBIAC AD-B199939).

The corrosivity of seawater solutions of calcium hypochlorite, lithium hypochlorate, and Fichlor (sodium dichloroisocyanurate) were studied with respect to solution pH. Metals tested were stainless steel, aluminum, copper-nickel, and mild steel (CBIAC AD-B140285 and AD- B140286).

The effect of seawater solutions of calcium hypochlorite, lithium hypochlorite, and sodium dichloroisocyanurate were studied on non-skid and alkyd painted surfaces at room temperature (CBIAC AD-A220422).

5.5.1.3 Technical Assessment. Chemical oxidation technology is primarily applicable to the decontamination of the agents VX and HD. In the case of VX, the reaction chemistry is very complex and the products formed are highly dependent on the pH of the solution. For example, in acidic solutions the nitrogen in the VX molecule is protonated and the sulfur atom is preferentially oxidized converting VX into the corresponding alkyl phosphonic acid and sulfonic acid. However, in neutral and basic solutions the nitrogen atom is oxidized faster than the sulfur atom thereby forming a stable, and toxic N-oxide species. In the case of HD, the sulfur atom is readily oxidized to the corresponding sulfone or sulfoxide with few complications.

The principal shortcoming of oxidation technology is the corrosivity of the decontamination solutions. Any solution of an oxidant such as bleach, which is strong enough to detoxify gross chemical agent contamination, will also be corrosive to materials such as polymers, paints, and metals. Recognizing this problem, many researchers have investigated techniques designed to minimize the corrosivity of oxidant solutions. By designing a system where the corrosive oxidant is partitioned away from the surface likely to be corroded, corrosion problems could at least be minimized. One example of this strategy is the microemulsion technology where the aqueous phase forms micelles within an organic solvent. Once in solution the agent reacts with oxidants such as the hypochlorite ion dispersed throughout the aqueous micelles in the microemulsion. Because of the unique ability to detoxify VX and HD, the oxidation technology will continue to be investigated to find less corrosive and more effective decontaminants.

5.5.2 Nucleophilic Substitution

Nucleophilic substitution reactions involve the nucleophile (one atom or group of atoms) that displaces or replaces the leaving group (another atom or group of atoms) depending on the mechanism of the reaction. The nucleophile is a group that contains a lone pair of electrons and possibly has a negative charge and thus seeks a positive charge other than H^+. The leaving group is replaced by the nucleophile in the substitution reaction. The phosphorous atoms in chemical nerve agents are examples of the centers of positive charge (the electrophile) for which the nucleophile has a special attraction.

Nucleophiles that have been used for the detoxification of chemical agents are hydroxide, water (hydrolysis), oximes, hydroxamics, thiosulfate, the hydroperoxide ion (HOO^-), and the hypochlorite ion (ClO^-). Typically the hypochlorite ion is classified under the heading of oxidants (oxidation reaction). For the detoxification of agents such as GA, GB, GD, VX, and HD, various nucleophiles even though they are less basic, such as hypochlorites, hydroperoxides, oximes, and hydroxamics, tend to have somewhat more rapid reaction rates than the hydroxide anion. Oximes can also be used as antidotes for organophosphate exposure.

In the laboratory, pyrocatechol and pyrogallo anions were able to rapidly hydrolyze organophosphates; however, the results have not evolved into practical full-scale operations. For large-scale destruction of mustard, the proposed nucleophiles include amines and ions such as hydroxide, phenolate, and thiosulfate. Sodium thiosulfate reacts rapidly with mustard but this reaction has not been applied to bulk quantities. Sodium hypochlorite has been developed for large-scale decontamination operations.

Strong Base Hydrolysis. A strong base, such as calcium oxide, calcium hydroxide, sodium hydroxide and potassium hydroxide, produces a high concentration of hydroxide ions upon mixing with water. These compounds, when in solution, are effective as a hydrolysis agent in reacting with chemical agents. Each compound has a different solubility in water with sodium hydroxide being most widely used to prepare a solution since it has the highest solubility of these compounds; calcium oxide and calcium hydroxide are the least soluble.

In the reaction with GB, the hydroxide ion (OH^-) disrupts and breaks the phosphorus-fluorine bond and forms a P – O bond. This reaction can be catalyzed by the addition of sodium hypochlorite (common bleach) which dissociates into sodium cations (Na^+) and hypochlorite anions (OCl^-).

The hydroxide ion is not as effective for VX as it is for GB. In VX, the critical bond is the phosphorus-sulfur bond. While the hydroxide ion will break the P – S bond, there is a competing reaction that replaces the ethoxy group with a hydroxl group, forming a compound called EA 2192. This is a highly toxic compound that is approximately a third as toxic as VX. Depending on the conditions, up to 14% of EA2192 will be produced. In addition, the solubility of VX in a basic solution such as hydroxide is low which will affect the reaction rate.

The hydroxide ion can be used to detoxify mustard, HD. In the reaction with HD, the hydroxide ion replaces the chlorine atom and hydrochloric acid. The solubility of HD in an aqueous system such as hydroxide is low and much of the reaction occurs at the interface between the HD and water. In order to increase the reaction rate, mixing the reaction mass and an increase in temperature to around 100 °C are techniques often used.

Oximes. Oximes are a class of compounds that are considered to be either alpha nucleophiles or micellar nucleophiles. Amylose oxime is an alpha nucleophile that readily reacts with G agents, and also has favorable reaction kinetics as measured in the laboratory for VX. Dodecylpyridinium-3-aldoxime iodide is an example of a micellar nucleophile. Micellar oximes such as dodecylpyridinium-3-aldoxime iodide tend to concentrate at the surface of a solution where more favorable concentration effects should enhance the hydrolysis of organophosphates. An example of this is the half-life of VX in a pH 9.3, 10^{-3} molar solution of dodecylpyridinium-3-aldoxime iodide that was measured to be 40 seconds.

Hydroxamic acids. Hydroxamic acids are a class of compounds that are considered to be alpha nucleophiles. Ethylenediaminetetracetohydroxamic acid is an example. It has been shown that hydroxamic acids react rapidly with G agents, and also have favorable reaction kinetics as measured in the laboratory for VX.

Sodium sulfide. Sodium sulfide, Na_2S, is soluble in water and forms a solution of sodium hydroxide (NaOH) and sodium thiosulfate ($Na_2O_3S_2$) when dissolved in water. 15% sodium sulfide in a mixture of glycerol, ethanol and water at ambient temperature was able to destroy HD in 20 hours. Greenpeace in a review of alternative technologies for the demilitarization of chemical weapons refers to the use of a 20% solution of sodium sulfide in the destruction of sulfur and nitrogen mustard, and questions the effectiveness of Na_2S in the destruction of G and V agents. Sodium sulfide has also been reported to be a conceivable reaction product from the reduction of GB, VX, and HD, and could not be responsibly discharged into the environment.

Monoethanolamine. Monoethanolamine (MEA), C_2H_7NO, is a strong base in and of itself, and has successfully been used in the decontamination of HD. The half-life of HD in MEA at 57°C has been reported to be 11 minutes. GB has also been successfully decontaminated by dissolution in MEA and heating of the solution. Reaction products are less toxic than the initial GB, and can be stored or shipped to another site for further processing. One advantage in the use of MEA for the decontamination of GB is that the volatility of GB is greatly reduced, the reaction is much cleaner in terms of reaction products, and corrosion to processing equipment is minimal. When combined with 4-N,N-dimethylaminopyridine, monoethanolamine has been used in the destruction of GB. MEA has also been used for the detoxification of organophosphorous pesticides in work sponsored by the U.S. Air Force in the late 1960s and early 1970s. A pesticide to MEA ratio of 1:10 was reported to be effective, and that the resulting reaction mixtures were less toxic to fish than the decontamination solution alone.

Alkoxides. Strong bases such as sodium hydroxide (NaOH) can also dissolve into an organic solvent forming a very strong basic solution. For the decontamination of chemical agents, methanol or ethanol can be added to an aqueous solution of NaOH or potassium hydroxide (KOH). Also, the NaOH or KOH can be dissolved directly in the methanol or ethanol. The addition of one of these alcohols enhances the solubility of the chemical agent into the decontamination/detoxification solution.

In the presence of excess KOH in methanol or water, the G agents should be effectively detoxified quite rapidly as they are in the presence of NaOH. In neat methanol, KOH would likely react too slowly (as in the case of NaOH) with HD to be effective, but in ethanol, the half-life of the destruction of HD would likely approximate that of the reaction in the presence of NaOH, which is 11 hours. VX would be much more soluble in an alcoholic solution of KOH as it is in an alcoholic solution of NaOH, but because of the flammability of the alcohols, its use has been mitigated.

For the detoxification of GB in the presence of methanol, the methoxide ion (CH_3O^-) is formed and behaves similarly to the hydroxide ion in aqueous solution in that it disrupts and breaks the phosphorous-fluorine bond forming a phosphorous-oxygen bond. In the case of a decontamination/detoxification solution that contains methanol, ethanol, or another alcohol, flammability and sources of ignition also become a concern. Also, toxicity of the alcohol must be considered.

CD-1. CD-1 is an all-purpose decontaminant developed by the U. S. Air Force, and is similar to DS2. CD-1 is a mixture of monoethanolamine (55 vol %), 2-hydroxy-1-propylamine (45 vol %), and lithium hydroxide monohydrate (2.5 % by weight). Initial testing of the CD-1 decontaminant demonstrated rapid destruction of GB at either a 10:1 or 5:1 (decontaminant:agent) ratio, and that is was inferior to DS2 for the destruction of HD due to the formation of vinyl chloroethyl sulfide which is itself quite toxic.

When both GB and CD-1 are aerosolized at a 1:10 concentration ratio and allowed to react, it was found that at least 98% of the GB was destroyed in 6 minutes, and in excess of 99% was destroyed in 30 minutes. When VX is mixed with liquid CD-1 at a concentration of 1% by weight of VX, 99.2% of the VX was destroyed after 15 minutes. For GB dissolved in CD-1, 99.94% of the GB was destroyed within 2 minutes.

Alkali Metal Hydroxides. Alkali metal hydroxides such as sodium hydroxide (NaOH), potassium hydroxide (KOH), and lithium hydroxide (LiOH) have been utilized for the detoxification of chemical agents. LiOH is one of the components in the U. S. Air Force's CD-1 all purpose decontaminant.

NaOH is applicable for the detoxification of persistent agents and G agents where the main reaction is alkaline hydrolysis. In the reaction with GB, the hydroxide ion (OH^-) disrupts and breaks the phosphorus-fluorine bond and forms a P – O bond. This reaction can be catalyzed by the addition of sodium hypochlorite (common bleach) which dissociates into sodium cations (Na^+) and hypochlorite anions (OCl^-).

The hydroxide ion is not as effective for VX as it is for GB. In VX, the critical bond is the phosphorus-sulfur bond. While the hydroxide ion will break the P – S bond, there is a competing reaction that replaces the ethoxy group with a hydroxl group, forming a compound called EA 2192. This is a highly toxic compound that is approximately a third as toxic as VX. Depending on the conditions, up to 14% of EA2192 will be produced. In addition, the solubility of VX in a basic solution such as hydroxide is low which will affect the reaction rate.

The hydroxide ion can be used to detoxify mustard, HD. In the reaction with HD, the hydroxide ion replaces the chlorine atom producing hydrochloric acid as a by-product. The solubility of HD in an aqueous system such as hydroxide is low and much of the reaction occurs at the interface between the HD and water. In order to increase the reaction rate, mixing the reaction mass and an increase in temperature to around 100 °C are techniques often used.

M258/M258A1/M280. The M258 skin and personal equipment decontamination kit came into existence after a Soviet-made personal decontamination kit was recovered from Soviet vehicles used by the Egyptian Army in the 1973 Yom Kippur War with Israel. The U. S. Army reproduced the decontamination chemistry used in the Soviet kit and introduced the M258 kit in 1974. In the 1980s the Army introduced the M258A1 and M280 kits which also utilize the same chemistry as the M258 kit.

All kits contain two sealed packets. Packet I contains a towelette (Towelette I) prewetted with a decontamination solution consisting of 72% ethanol, 10% phenol, 5% sodium hydroxide, 0.2% ammonia, and approximately 12% water. The decontaminating solution in the towelette is effective for detoxification of G agents by rapid nucleophilic substitutions at the phosphorous atom. The phenoxide, ethoxide, and hydroxide anions that are formed from the decontaminating solution displace the fluoride ion. For VX, the same reactions are quite slow. Packet II contains a towelette (Towelette II) impregnated with Chloramine-B, and a glass ampoule filled with an aqueous solution containing 5% zinc chloride, 45% ethanol and 50% water. Towelette II effectively decontaminates, via oxidation, both HD and VX quite rapidly. The two towelettes are to be used consecutively.

Mixed Water/Non-Aqueous Solvent Based. Strong bases such as sodium hydroxide can also dissolve into a water alcohol mixture. Upon dissolution the OH^- ion is formed as in an aqueous system, but the presence of the organic alcohol makes dissolution of the agent much easier. Once dissolved decontamination of the agent proceeds rapidly even for thickened agents.

Non-Aqueous Based. Strong bases such as sodium hydroxide can also dissolve into an organic solvent forming a very strong basic solution. The most well known member of this technology is decontaminating solution 2 or DS2. This solution is made up of 70% diethylenetriamine (DETA), 28% 2-methoxyethanol (also known as ethylene glycol monomethylether, EGME), and 2% sodium hydroxide (NaOH). In this solution NaOH reacts with EGME forming the ethoxide, when DETA is added to this solution any free sodium ions are rapidly bound up by the DETA. This causes the OH^- ions to be highly reactive effectively increasing the base strength of the solution.

5.5.2.1 Current Applications. DS2 is currently the Army's primary decontaminant for hasty decontamination of vehicles and equipment. The reaction of G agents with strong bases such as sodium and potassium hydroxides has been recognized since the end of World War II. Because of the poor reactivity of VX with aqueous strong bases, DS2 was formulated. DS2 combines the solubilizing power of a non-aqueous solvent (diethylenetriamine) to get the agents VX, GB, and HD into solution were they can be attacked and destroyed. The 2-methoxyethanol reacts with the sodium hydroxide forming the sodium salt and subsequently freeing the hydroxyl ion into solution. Because the sodium ion is tightly bound to the 2-methoxyethanol as a salt, the reactivity of the hydroxyl ion is significantly enhanced. This makes DS2 a very strong base capable of decontaminating all the chemical agents.

DS2 was formulated to be a general purpose reactive decontaminate that would be ready to use over a large temperature range, and have long term storage stability. DS2 is a nonaqueous, polar liquid and consists by weight of 70% diethylenetriamine ($C_4H_{13}N_3$), 28% ethylene glycol monomethyl ether ($C_3H_6O_2$) commercially known as Methyl Cellusolve® , and 2% sodium hydroxide (NaOH). The reactive component of DS2 has been identified as the conjugate base of the ethylene glycol monomethyl ether, $CH_3OCH_2CH_2O^-$.

DS2 reacts instantly towards the G agents, VX, and HD at ambient temperatures. DS2 is noncorrosive to most metals, but it can damage paints, plastics, rubbers and leather materials. DS2 is flammable and cannot be used in conjunction with strong oxidizing agents such as bleach, which cause it to spontaneously combust.

DS2 comes ready to use in containers ranging from 1-1/3 quart cans to 5-gallon pails. Application of DS2 can be by the ABC-M11 portable decontamination apparatus or the M13 DAP. DS2 is allowed to remain in contact with the contaminated surface for up to 30 minutes, and then rinsed off with water. DS2 is most effective when application is followed by a scrubbing action.

A replacement formulation for DS2, termed DS2P, has been designed and tested. DS2P is a nonaqueous, polar liquid and consists by weight of 70% diethylenetriamine ($C_4H_{13}N_3$), 28% propylene glycol monomethyl ether (PGME), and 2% sodium hydroxide (NaOH). The reactive component of DS2P has been identified as the conjugate base of the propylene glycol monomethyl ether, $H_3OCH_2CH_2CH_2O^-$. The new formulation replaces the ethylene glycol monomethylether, EGME, with the non-cancer causing chemical propylene glycol monomethyl ether, PGME.

DS2P reacts instantly towards the G agents, VX, and HD at ambient temperatures. DS2P is noncorrosive to most metals, but it can damage paints, plastics, rubbers and leather materials. DS2P is flammable and should not come into contact with strong oxidizing agents such as bleach. DS2P has been shown to be as effective as DS2 in removing HD, TGD, and VX from painted metal panels. It was demonstrated that DS2P could be prepared in large quantities with no degradation in properties.

5.5.2.2 Evaluation Results. Nucleophiles such as hypochlorites, hydroperoxides, oximes, and hydroxamics, are effective for the detoxification of agents such as HD, GA, GB, GD, and VX. However, only sodium hypochlorite has been employed for full-scale decontamination operations.

The reactions of 2-chloroethyl methyl sulfide (CEMS) and HD with DS2 were investigated by ^{13}C NMR spectroscopy. It was noted that as the amount of water was increased in the DS2-water solutions, the reaction mechanism changed from a rapid elimination to a slower nucleophilic SN1 process. (CBIAC AD-A267569). Reactions of GA, GB, GD, HD, VX, O,S-diethylmethylphosphonothiolate (DEMPS), and 2-chloroethyl methyl sulfide (CEMS) with DS2 were also investigated. Variations in the reaction profiles provided information about the mechanism of DS2 and factors influencing its effectiveness. It was found that at higher concentrations of water, the non-aqueous chemistry of DS2 was destroyed, and that nucleophilic substitution reactions predominated. (CBIAC AD-P200934).

In aqueous ethanol, mustard, bis(2-chloroethyl) sulfide (HD), was found to react with the potassium salts of benzohydroxamic acid, phenol, and 2,3-butanedione monoxime to yield solid crystalline products. Analysis of the products showed that the respective oxygen anion group had substituted both chloride atoms of HD. This indicated that the nucleophilic substitution of HD was preferred over the elimination mechanism. (CBIAC AD-A224001)

Alkaline hydroxides, carbonates, alcohols, phenols, amines, and S-based compounds are frequently used in the decontamination of chemical agents. Alkaline reagents are of particular interest both because of their hydrolytic characteristics and with their use in nucleophilic substitutions as supporting mechanisms in the decontamination of chemical agents. A nucleophilic substitution in a molecule of HD depends upon the nucleophilic tendency of the reactant, and in a molecule of sarin (GB) upon the alkalinity of the reactant. For these reasons the decontamination of HD involves the use of highly nucleophilic decontaminants, and in the case of the decontamination of GB, the use of decontaminants with a high negative charge. (CBIAC AD-B103496).

5.5.2.3 Technical Assessment. Nucleophilic substitution is a primary technology, along with oxidation technology, for decontamination of chemical agents. DS2 is an effective decontaminant for all agents due to the unique combination of a solvent that readily dissolves agents and the associated chemistry that produces a solution that is highly basic. The combination of high basicity and a non-aqueous environment causes all agents to be rapidly detoxified by DS2 solutions. However, DS2 is corrosive to polymers and paints and contains a cancer-causing component (ethylene glycol monomethyl ether). A new formulation for DS2, called DS2P, has been prepared and demonstrated to be as effective as DS2. However, DS2P still has the materials compatibility problems associated with DS2. Therefore, research is focused on preparing a DS2 and S2P replacement that is as effective in decontaminating agents but which exhibits few, or none of the material compatibility problems of DS2 and DS2P.

5.5.3 Photochemical

Photochemical reactions involve interactions of radiant energy, such as light, with chemical systems, which results in a chemical decomposition (photolysis or photodecomposition). These reactions involve electronic excitations of compounds with quanta of energy from wavelengths of electromagnetic radiation in the ultraviolet region of the spectrum. When a molecule absorbs a photon of appropriate energy and an electron is promoted to an excited state, the molecule while it is in this alternate state may then take part in a reaction. There are several possibilities for the reaction that the excited molecule may take such as rearrangement, dissociation, addition, or transfer of energy to another molecule, which subsequently undergoes a reaction.

Organophosphate pesticides can and do undergo photochemical reactions induced by ultraviolet light in the natural environment. This results in the detoxification of those pesticides by the mechanism of photodecomposition. Additionally, it is known that organophosphorous nerve agents in the environment also decompose through photodecomposition.

5.5.3.1 Ultraviolet (UV). This process involves the activation of a molecule's electrons to a higher energetic state by an energy transfer from the impinging ultraviolet light. The molecule absorbs energy from ultraviolet light and is promoted to an activated state. Chemical reactions such as rearrangement or dissociation of the molecule in the excited state may then occur.

5.5.3.1.1 Current Applications. In the purification of air and water for both microbial contaminants and volatile organic compounds, ultraviolet light has been frequently used. A two-step decontamination process for treatment of heavily polluted waters with toxic organic chemical content and bacterial content has been utilized by an initial filtration step followed by ultraviolet treatment of the effluent. In the laboratory, UV light has been used to dehydrochlorinate dioxins.

5.5.3.1.2 Evaluation Results. A Literature Search and personal interviews were conducted to assess the current status of decontamination of electronic equipment. Decontamination by UV light was one of the processes evaluated and found to be a promising technique pending further investigation (CBIAC AD-B122257).

5.5.3.1.3 Technical Assessment. Heavily polluted waters have been treated with a two-step decontamination process involving one step filtration and then UV treatment. Application to CB agents is therefore technically feasible, as the equipment is commercially available. A committee for the investigation of the detoxification of chemical weapons found that the influence of photodecomposition for chemical agents is unclear with limited information.

5.5.3.2 UV-Assisted. Several processes with ultraviolet (UV) light in combination with another system have been investigated for the detoxification of hazardous chemicals. Ultraviolet (UV) light is quite effective in splitting hydrogen peroxide (H_2O_2) into active hydroxyl free radicals (OH°) as illustrated in the following equation: $H_2O_2 + UV = 2\ OH^\circ$. Also, UV light is capable of decomposing ozone (O_3) to hydroxyl free radicals. Hydroxyl free radicals can effectively oxidize many toxic organic compounds and destroy bacteria. In addition, O_3 will react with the hydroxide ion in a high pH solution in the presence of UV light to form the hydroxyl radical.

5.5.3.2.1 Current Applications. The technology has been developed for sterilization devices that combine ultraviolet light and ozone to sterilize products, water, food, and air. Application of a photodegradation system has been utilized for the treatment of various dilute waste streams contaminated with various organic compounds. Current studies involving the photochemical destruction of volatile organic molecules present as contaminants in air by irradiation of a catalyst with UV light are underway.

5.5.3.2.2 Evaluation Results. In the laboratory, several chemical agent simulants were studied by condensing 50 % hydrogen peroxide (H_2O_2) vapor and 254 nm ultraviolet (UV) light. The hydroxyl radicals produced from the splitting of the H_2O_2 by UV light are known to rapidly react with most organic molecules. The solubility of the chemical agent simulant in the water-like H_2O_2 condensate primarily determined the rate of reaction. The agent simulant for VX, the insecticide dimethoate, was effectively destroyed because of its relatively high solubility in water. Only partial decontamination was attained for the chemical agent simulants phenyl half-mustard and malathion as they are less soluble in water (CBIAC AD-A248070).

An additional study for decontamination applications was conducted with the organophosphorous pesticide malathion to determine if there are any advantages in combining aqueous oxidizers with UV light. The aqueous oxidizers used in the study were hypochlorite, perborate, peroxide, peroxydisulfate, and percarbonate anions. It was found that the use of UV light with the systems of aqueous oxidizer resulted in loss of malathion up to five times faster as the systems of aqueous oxidizer without UV light (CBIAC AD-P200616).

The destruction of volatile organic compounds in ground water has been of major interest. In batch tests of synthetic wastewater containing 1,2-dichloroethene, trichloroethene, dichloromethane, and benzene, the process of hydrogen peroxide catalyzed by UV light was found to be effective in the destruction of these contaminants (CBIAC AD-A245165).

It was reported that the use of light activated photoelectrochemical diode particles could be used to decontaminate the nerve agent simulant DMMP. Investigation of the reactivity of zinc oxide (ZnO) and titanium dioxide (TiO_2) with the nerve agent simulant demonstrated that DMMP vapors are sorbed onto the surface of the semiconductor oxide patrticles. When irradiated with light above the bandgap of ZnO, the sorbed DMMP underwent a nonreversible decomposition rearrangement on the surface. This nonreversible decomposition rearrangement also occurs when the ZnO/DMMP is heated (CBIAC AD-A183937).

5.5.3.2.3 Technical Assessment. Additional investigations into the efficiency of the decontamination/detoxification of mixed wastes and concentrated wastes by photodegradation systems are required. From a review of the literature, photodegradation systems demonstrate the ability to degrade contaminants in waste streams. However, a limitation to the success of the process was dependent on the optical clarity of the waste water being treated. Additionally, a committee for the investigation of destruction of chemical agents and munitions did not find any available information discussing the treatment of concentrated organic wastes or chemical agents.

5.5.4 Enhancement Techniques

5.5.4.1 Surfactants. There are three categories of surfactants that are currently in use. The categories are anionic surfactants, cationic surfactants, and nonionic surfactants. Sodium lauryl sulfate is an example of an anionic surfactant, tetramethylammonium hydroxide is an example of a simple cationic surfactant that is also a quaternary ammonium complex, oleyl imidazoline is an example of a more complex cationic surfactant, and octoxynol ($C_{34}H_{58}O_{12}$) is an example of a nonionic surfactant. It has been found that anionic surfactants are generally more powerful in terms of solubilizing chemical agents into an aqueous solution than cationic or nonionic surfactants. The intent of a surfactant is not to detoxify the chemical agent, but to solubilize it more efficiently into a solution that can detoxify it.

5.5.4.1.1 Current Applications Surfactants are currently used in several decontamination formulations currently used by the U.S. Army and U.S. Navy.

5.5.4.1.2 Evaluation Results. In 1991, the Naval Research Laboratory (NRL) published a report by Matuszko entitled, "The use of MIL SPEC Surfactants/Cleaners in the NRL-Recommended Decontamination Formulation", NRL Memorandum Report 6781, February 18, 1991. The report detailed a method for evaluating MIL SPEC surfactants/cleaners for use in a decontamination formulation. It was stated that while the choice of surfactant was important, any surfactant used had to meet certain criteria. The surfactant had to be an effective cleaner in both freshwater and seawater, it had to be compatible with the buffer used to maintain the pH of the formulation, and the surfactant had to be compatible with the oxidizer.

Varying solutions (0.1%, 1% and 10%) of surfactant in seawater were prepared. If the resulting solutions were either cloudy or milky, it was concluded that the surfactant was not adequately dissolving/dispersing into the seawater. A 1% surfactant/cleaner in buffer solution was used to evaluate the effect of the surfactant on the buffer. The pH of the solutions were measured over a two hour time period, and the pH of all the solutions essentially remained constant over the experimental time period. The surfactants did raise the pH of all the solutions, however, it was considered to be negligible as the pH was only raised an average of 1% as compared to the pH of the buffer solution alone. In the evaluation of the surfactant-oxidizer compatibility, surfactants were added at the 1% level to the decontamination solutions which contained the buffer. Available chlorine levels were measured over a two hour time period to determine compatibility as compared to a buffer-oxidizer only solution. The experiment was performed in triplicate. It was determined that the surfactants tested had little if any effect on the available chlorine concentrations (oxidizing power) provided by the oxidizer.

In an U.S. Army study, specific physical interactions of surfactants in solution were measured and compared. Most of the following properties were measured: hydrophile-lipophile balance (HLB), droplet spreading, liquid/vapor surface tension, pH, critical surface tension of the Surface-Active Displacement Solutions (SADS) residues, effectiveness in contaminant removal, effect on paint hardness, corrosive nature, and resistance to recontamination. From these tests, four SADS were then developed and tested under controlled conditions using solutions formulated using seawater and formulations using pond or well-water. From this study, two of the four SADS formulations were found to be superior, and based upon cost, the fluorosurfactant was eliminated as it was considered too expensive for widespread use. It was also determined that the type of water used for dilution of the SADS candidate was not critical (CBIAC ADB064152).

5.5.4.1.3 Technical Assesment. As pointed out above, surfactants are used to help to dissolve chemical agents into solutions containing decontaminants. There are many commercially available surfactants such as laundry detergents and emulsifying agents. These compounds can be incorporated into various decontamination technologies such as microemulsions, oxidation, and nucleophillic substitution to help to get the agent into solution with the decontaminant. The general case for all chemical agents is that once into solution with a decontaminating agent decontamination of the agent occurs quickly. Therefore, surfactants are an important technology for assisting in the decontamination of chemical agents.

5.5.4.2 Organic Additives. In this discussion, organic additives are compounds that are added to an aqueous based decontamination solution to enhance the solubility of species such as organophosphorous compounds, G and V series agents, and HD into water. Some of these organic additives are considered to be ionic or nonionic surfactants such as sodium lauryl sulfate or Poloxalene™, respectively, and have been discussed in an earlier section. Considered here are Methyl-Cellusolve® (2-methoxyethanol), and 3-methylsulfolane which can be thought of as being co-solvents.

Methyl-Cellusolve® is the monomethyl ether of ethylene glycol ($HOCH_2CH_2OCH_3$) and has been used in formulations such as DS-2. DS-2 contains 28% Methyl-Cellusolve®. Another decontamination solution consisting of 70% Methyl-Cellusolve® and 30% of (50% aqueous sodium hydroxide solution and monoethanolamine) has been reported to be effective in the decontamination of HD, and should be effective in the decontamination of the G agents and VX. The presence of Methyl-Cellusolve® in the solution increased the solubility of the chemical agents into an aqueous containing decontamination solution by reducing the surface tension of the water. Methyl-Cellusolve® by itself is relatively noncorrosive. Methyl-Cellusolve® can also be considered the active or reactive component in a decontamination solution containing both it and a strong base such as sodium hydroxide. 3-Methylsulfolane ($C_5H_{10}O_2S$) is also noncorrosive compound that can also be added to water as a co-solvent in order to enhance the solubility of compounds that are relatively insoluble in water.

A variety of alcohols could also be used as cosolvents in an aqueous based decontamination solution.

5.5.4.2.1 Current Applications. In a report submitted to the U.S. Army by Argonne National Laboratory, mention is made of the 70% Methyl-Cellusolve® decontamination solution, and its effectiveness against GB. It would also be expected that a decontamination solution containing 3-methylsulfolane could also be used in place of Methyl-Cellusolve® if there was a reactivity or solubility problem. Also refer to the section on DS2, Section 5.5.2.2.1, for more information on applications.

5.5.4.2.2 Evaluation of Results. As reported earlier for DS2, Methyl-Cellusolve® is an effective co-solvent for the various agents, thickened and non-thickened. Similar results should be observed for 3-methylsulfolane.

5.5.4.2.3 Technical Assessment. As DS2 is being replaced because of environmental concerns over the ethylene glycol monomethyl ether (EGME) aka, Methyl-Cellusolve®, further work should not be encouraged using EGME as a co-solvent. Perhaps 3-methylsulfolane could be used as a replacement for Methyl-Cellusolve®. Perhaps ethylene glycol monopropyl ether could be investigated as another replacement for Methyl-Cellusolve®.

5.5.4.3 Microemulsions. Chemical agents are organic compounds that exhibit a limited solubility in water. Many decontaminants such as calcium hypochlorite and hydroxide ions are highly soluble in water. Because of the limited solubility of chemical agents in water, the time needed to decontaminate the agent is determined primarily by the solubility of the agent in the mixture of water and decontaminant. Microemulsions are thermodynamically stable mixtures of water, oil, surfactants, and cosurfactants that appear macroscopically as a homogenous phase. Different water-soluble decontaminants can be dissolved into a microemulsion leading to a chemical system containing very small organic droplets dispersed into water (for an oil in water microemulsion) containing the decontaminant.

When a chemical agent encounters a microemulsion system, it is dissolved (partitioned) into the organic phase of the microemulsion. Once dissolved, the agent can react with the water-soluble decontaminant at the surface of the organic portion of the microemulsion. It is important to note that the rate of agent decontamination is related to the size of the microemulsion particles. The smaller the particles can be made, the faster the decontamination process. This is due to the high surface area of the reaction surface with respect to the amount of chemical agent dissolved, and the short diffusion paths from the center of the microemulsion particle and its surface.

Related to microemulsions are reactive foams and gels which are polymeric materials with reactive sites that can readily decontaminate chemical agents. Oxidants, nucleophiles, catalysts and/or enzymes are bound to the polymeric backbone of the foams or gels. When the chemical agents come into contact with the foam or gel, they encounter the reactive site and are detoxified. The foams can be mixed with various solvents including water, to aid in their deployment. Foams can be engineered to use limited amounts of solvent in order to reduce their dependency upon solvent volume, and to aid in the clean up after deployment. After the solvent evaporates, the foams collapse and turn it a powder allowing for a simplified, final clean up operation.

Gels are formulated similarly to reactive foams except that they are a blending of materials and solvents, and are much more viscous. As they dry, gels turn into powders, and can be easily cleaned up. As a result of their greater viscosity than foams, gels are applied in different manners. Foams can be applied using pumps, and gels are typically spread.

5.5.4.3.1 Current Applications. C8 is an emulsion formulated by the Germans as a multi purpose decontaminant reagent. The C8 emulsion consists of, by weight, 15% tetrachloroethylene (C_2Cl_2) which serves as the continuous phase, 76% water, 1% anionic surfactant, and 8% calcium hypochlorite ($Ca(OCl)_2$). C8 is effective in the decontamination of VX, G agents, and HD. Because the tetrachloroethylene is the continuous phase, it is noncorrosive and for thickened chemical agents, is as good a solvent as pure tetrachloroethylene. C8 can penetrate into paint in order to dissolve and react with chemical agents that may be imbedded into the paint without damaging the paint. When sprayed, the C8 emulsion forms a thin continuous film over the surface and remains in contact with the surface to allow for sufficient contact time in decontaminating/detoxifying the chemical agents. After decontamination, the C8 can be flushed off with water.

The multipurpose chemical, biological decontaminant (MCBD) is a microemulsion system is a stable emulsion at pH 10, containing less tetrachloroethylene than the German C8 emulsion system, and is partially catalytic. MCBD was designed to decontaminate the G agents, VX, and HD. The formulation of MCBD is 60% water which is the continuous phase, 7% tetrachloroethylene (C_2Cl_2), 4% Fichlor, 28% *n*-cetyl trimethylammonium chloride (CTAC) which is a surfactant. A small amount of tetrabutylammonium hydroxide as a cosurfactant and phase transfer catalyst, 0.1% sodium 2-nitro-4-iodoxybenzoate (IBX) as a nucleophilic catalyst for G agents, and sodium borate as a buffer are also included. The effective decontamination agent in MCBD for VX is the Fichlor (dichloroisocyanurate). For G agents, it is the IBX, and for HD, the hydroxide ions generated in the emulsion are responsible.

MCBD can be sprayed, poured or wiped onto a surface that requires decontamination. As it is an emulsion of polar and nonpolar solvents, it will solubilize polar agents such as the G agents, nonpolar agents such as HD, and agents like VX which have an intermediate polarity. When sprayed, the MCBD microemulsion forms a thin continuous film over the surface and remains in contact with the surface to allow for sufficient contact time to decontaminate the chemical agents. After decontamination, the MCBD can be flushed off with water.

5.5.4.3.2 Evaluation Results. An oil/water microemulsion containing a 2-fold excess of hypochlorite and a low molecular weight alcohol added as a cosurfactant was experimentally shown to rapidly oxidize half mustard forming the non-toxic sulfoxide quantitatively (CBIAC AD-P200839).

The oxidation of a mustard simulant by oxone and periodate ion in cationic micelles was studied. It was determined that oxone promotes the decomposition of thiophosphinate esters by oxidation of the sulfur atom which promotes the dissolution of the P-S bond (CBIAC AD-A253508).

The solution kinetics of the dissappearance of GD, TGD, VX, and HD were investigated in microemulsions containing o-iodosobenzoic acid (IBA) as the reactive ingredient. The composition of the IBA microemulsions (w/w) were 16.5% CTAC (cetyltrimethyl ammonium chloride), 11.6% TBAH (tetrabutylammonium hydroxide), 1.4% adogen 464, 63.1% water and 7.4% perchloroethylene. The half-lives of GB, HD, and VX in the microemulsion were < 1 min, 3 hr, and 1 hr respectively (CBIAC AD-B141109).

5.5.4.3.3 Technical Assessment. Microemulsions offer potential effectiveness for the decontamination of chemical agents and possibly for biological agents. By combining aqueous and non-aqueous phases into a stable microemulsion, problems with agent solubility that generally limits reactivity can be overcome. Because the microemulsions combine both aqueous and non-aqueous phases, different decontaminants or combinations of decontaminants can be used. The German C8 emulsion has been reported to exhibit good decontaminating ability and be relatively non-corrosive. One drawback to microemulsions is the use of chlorinated hydrocarbons such as tetrachloroethylene or perchloroethylene as the organic phase. Chlorinated hydrocarbons are environmentally difficult to degrade and often produce a toxic by-product, vinyl chloride. Thus, use of these compounds is not desired from an environmental perspective.

5.5.4.4 Catalysts. A catalyst is a substance that increases the rate of a chemical reaction without itself being used up. One common way to speed up a chemical reaction is to raise the temperature of the reaction mixture. However, this method frequently produces unwanted side effects such as production of an unwanted species as product. A catalyst on the other hand accelerates a reaction without any change in temperature.

All catalysts operate in the same manner, they lower the activation energy, or the amount of energy needed to make the reaction proceed to product, by providing a completely different, lower energy pathway for the reaction progress. Catalysts combine transiently with the reactants to produce a short-lived chemical species that requires far less energy to produce product than the original reactant. Therefore, catalysts lower the amount of energy (heat) required for reactants to form products making it possible to carry out reactions at lower temperatures than without the catalyst. Conversely, under the same conditions of temperature and pressure, a catalyst will increase the rate of production of product from the reactants.

Catalysts can be classified into three principal types: heterogeneous catalysts, homogeneous catalysts, and enzyme catalysts. In homogenous catalysis the reactants, products, and catalyst are all dispersed in a single phase, usually a liquid phase. For example, the hydrolysis of ethyl acetate to acetic acid and ethanol is normally too slow to be measured. However, addition of hydrochloric acid to the solution causes the reaction rate to increase greatly, in this case the reaction is catalyzed by hydrochloric acid present in solution.

Homogeneous catalysis also operates in the gas phase. For example, in the lead chamber process for production of sulfuric acid, nitrogen dioxide gas is mixed with sulfur dioxide to form sulfur trioxide. Here, nitrogen dioxide acts as a catalyst.

Heterogeneous catalysis is by far the most important type of catalysis in industrial processes. In heterogeneous catalysis the catalyst is a solid and the reactants and products are either gases or liquids. The surface of the catalyst is usually the site of the chemical reaction. In order for the reaction to occur the reactant molecules must attach to the surface. There are two ways in which molecules can be attached to the surface of a solid through a process called adsorption. In physical adsorption, relatively weak intermolecular forces are responsible for holding the molecules on the surface. Physical adsorption plays no role or a very minor role in heterogeneous catalysis. The other kind of adsorption, called chemical adsorption or chemisorption, involves the formation of covalent bonds between the molecules and the solid. An important consequence of chemisorption is that when the molecule bonds to the surface the normal covalent bonds of the molecule are weakened, thereby making them more susceptible to chemical reaction at lower temperatures. An important physical parameter to consider for heterogeneous catalysts is the surface area of the catalyst. The rate of heterogeneous reaction is proportional to the surface area of the catalyst. Increasing the surface area provides for more chemisorption sites effectively increasing the number of molecules that can chemisorb then react to form product. For this reason heterogeneous catalysts are generally made in a way that will produce a large surface area for a given amount of solid. Solids used as catalysts are usually porous and extremely finely divided.

Enzymes are proteins specialized to catalyze biological reactions. Large biomolecules such as proteins and genetic materials are very sensitive to increases in temperature; increased temperature causes coagulation of proteins effectively inactivating their biological functions. Enzymes allow chemical reactions important to life to be carried out at physiological temperatures where large biomolecules are stable. Enzymes are discussed in more detail under Section 5.10.

5.5.4.4.1 Current Applications. A large number of industrial processes utilize catalysts to lower the amount of energy required to produce product and thereby reduce production costs. For example, platinum catalysts are used in the cracking process for production of gasoline from heavy crude oils. The production of sulfuric acid by the contact process utilizes a vanadium catalyst to convert sulfur dioxide to sulfur trioxide from which sulfuric acid is subsequently produced. Catalytic converters in the exhaust train of automobiles use a combination of catalysts to convert carbon monoxide and nitrous oxide into carbon dioxide and nitrogen and oxygen, respectively.

5.5.4.4.2 Evaluation Results. Published data on the catalytic oxidation of organic compounds using metal ions and oxygen or peroxide were reviewed. Oxidation with metal ions and oxygen are slow and noncatalytic, whereas metal ions, particularly iron, and peroxide are catalytic and rapid.

Oxidation rates of the VX simulant O,S-diethyl methylphosphonothioate (DEMP) under a wide variety of conditions of pH and concentration of peroxide, DEMP, and Fe ion were examined. The combination of iron (II) and hydrogen peroxide, known as Fenton's system, produces the highly reactive OH free radical that oxidizes any organic compounds in solution. Reaction rates increase with pH until >pH 5 where Fe ion becomes insoluble and unable to oxidize organics in solution. Oxidation reactions catalyzed by insoluble FeO_x are rapid only with organics sorbed onto the FeO_x surface. Efficiencies of oxidation range from 1% to 40%. Half-lives for oxidation of 1-3 mM DEMP were as short as 1 second at several pH values, with 3-20 nM Fe and 100-200 mM H_2O_2 (CBIAC AD-B139 614).

Experimental studies of catalytic and thermal decomposition of several chemical agents have been made to determine kinetic parameters for use in designing collective protection and air purification systems. Reaction products (in two cases GB and HD) were identified to ascertain toxicity of the process effluent. Rate constants and temperature coefficients were determined from the gas phase catalytic and thermal decomposition of isopropyl methyl fluorophosphonate (GB) and bis-(2-chloroethyl) sulfide (HD). Kinetic parameters for the gas phase thermal oxidation of VX were determined and are reported in a classified portion of this report.

The overall GB thermal conversion at atmospheric pressure appears to obey first order kinetics for temperatures between 300 °C and 400 °C. The decomposition products were propylene and methyl phosphonofluoridic acid. The catalytic decomposition of GB vapor in air over platinized alumina results initially in stoichiometric amounts of CO_2, H_2O, HF, and H_3PO_4. Catalytic oxidation declines with time and the decomposition shifts to the dealkylation reaction.

Similar studies with HD showed that overall first order kinetics was obeyed for both thermal and catalytic oxidation in the temperature range of 200 °C to 400 °C. The decomposition products were the same for catalytic and thermal oxidation. Catalytic oxidation produced ethylene, unreacted HD, and an unidentified compound in the temperature range 200 °C to 250 °C. At temperatures above 275 °C, CO_2, SO_2, HCl, and H_2O were found, but unreacted HD was no longer present. Thermal decomposition gave oxidation products above 335 °C (CBIAC AD-881 198).

The effects of intraparticle mass transfer on the complete oxidation of diethyl sulfide over a 1% Pt/Al2O3 was investigated using a fixed bed catalytic reactor. Reaction rates were recorded between 225 °C and 300 °C, diethyl sulfide concentrations between 5 and 250 ppm (v/v) and one atmosphere pressure. The reaction rate expression was determined in the absence of mass transfer resistances, using below 70 mesh catalyst particles. The oxidation kinetics of diethyl sulfide was determined to be zeroth order over the range of process conditions studied. Mass transfer resistances were observed at temperatures above 250 °C when employing 35/65 mesh catalyst particles. In these cases data could be correlated using a diffusion and reaction model which accounted for intraparticle gradients. At low sulfide concentrations, as will be encountered in catalytic systems designed for removal of chemical agents, mass transfer resistances are highly significant (CBIAC AD-A211499).

This report contains reports from a number of different researchers investigating catalytic decomposition of chemical agents. For example, the catalytic behaviors of analogs of 2-iodoxybenzene, specifically derivatives of iodoxybenzoic acids, were compared to the iodosobenzoic acid for hydrolysis of p-nitrophenyl diphenyl phosphate (PNPDPP) and p-nitrophenyl isopropylphenylphosphinate (NPIPP).

Also in this report, Drago, et al, described the synthesis and evaluation of a number of inorganic catalysts which use air to oxidize organic compounds. A large amount of work centered on the study of ruthenium based catalysts, for example cis-dioxo bis(2,9-dimethyl-1,10-phenanthroline)ruthenium (VI)hexafluorophosphate was demonstrated to be an efficient epoxidation catalyst for olefins. Also, a μ-oxo ruthemium trimer, Ru3(prop)6(H2O)3^{+} (where prop = propianate) was discovered to be an efficient alcohol oxidation catalyst. The heteropolytungstates, $MnPW_{11}O_{39}^{5-}$ and $CoSiW_{11}O_{39}^{6-}$, were studied in conjunction with iodosylbenzene, hydrogen peroxide, tert-butyl hydroperoxide, and oxygen pressure at elevated pressure to oxadize cyclohexene (CBIAC AD-B120 159).

5.5.4.4.3 Technical Assessment. Catalytic systems that exhibit high degrees of chemical specificity increased reaction rates, and long lifetimes have applications for demilitarization of chemical agent stockpiles, new self decontaminating coatings for military vehicles and equipment, and sorptive/self decontaminating materials for personnel and personal equipment decontamination. Development of new catalytic systems is necessary to meet the requirements for self-decontaminating coatings and personnel and personal equipment decontamination. The ability to immobilize the catalytic site in a matrix (coating or sorptive polymer) while retaining its catalytic ability must also be addressed. Novel surface modification techniques currently used for production of sorbent materials can be used to attach catalytic sites to the surface. Currently, much work is being done throughout the world to investigate novel reaction chemistry in supercritical fluids. From a catalytic point of view, supercritical fluids are ideal solvent systems. The diffusion of species in supercritical fluids is rapid, virtually eliminating mass transfer problems associated with heterogeneous catalysts. Also, reactive species such as hydrogen and oxygen are highly soluble in supercritical fluids. This allows for efficient hydrogenation and oxidation reactions to be carried out with minimum amount of catalyst. The final product distribution in a supercritical fluid has been demonstrated to be dependent on the supercritical fluid temperature and pressure. This allows for simple changes in temperature and pressure to affect the products of the reaction without changing the catalyst.

5.6 Sorbents

Sorbent technology uses materials that physically remove the liquid chemical agent from surfaces (e.g., skin) by absorbing the liquid agent into the material like a sponge absorbs water. What happens to the agent after sorption depends on the type of sorbent material used? Three types of sorbent materials used are simple sorbents, reactive sorbents, and catalytic sorbents.

5.6.1 Simple Sorbents

For simple sorbent materials such as soil, diatomaceous earth, activated charcoal, or some commercially available sorbents (XAD-7, XAD-2) the agent remains active in the sorbent material making the sorbent material toxic. A commonly fielded sorbent based system uses fuller's earth, a type of natural clay, in a mitt or package to sorb the agent. The soldier pats an area suspected of having liquid agent contamination with the mitt releasing the powdered fuller's earth. The agent is absorbed by the fuller's earth, then wiped or blown off the surface removing the contamination. Because the agent is not detoxified the contaminated fuller's earth remains a toxic substance.

Fuller's earth. Fuller's earth is a nonplastic form of kaolin that contains an aluminum magnesium silicate. The term fuller's earth is typically applied today to any clay that has an adequate purifying and/or decolorizing capacity. The most recognizable name for fuller's earth that is almost instantly recognizable by people is kitty litter, a general purpose absorbent used for spill cleanups as well as for feline hygiene. Fuller's earth is typically used industrially in the decolorizing of petroleum based oils, as a filler for rubber, in place of activated charcoal, and as a filtering medium. Fuller's earth may be used as a chemical agent decontaminant if no better method for the decontamination/detoxification of chemical agents is available. Crushed fuller's earth is most likely best suited for use as a personal decontamination agent. The decontamination process involved with fuller's earth is the physical removal of the agent from the skin of an exposed individual.

The fuller's earth will absorb a large portion of the agent when it is poured and rubbed over the exposed areas. Fuller's earth will not detoxify any chemical agents. It will only remove a portion of the agent and the contaminated fuller's earth must be considered toxic. At some point, the contaminated fuller's earth will need to be subjected to a detoxification procedure. Because of its great absorbing properties, fuller's earth is likely an effective decontaminant of G agents, HD and VX. Caution must be exercised when using fuller's earth so as not to inhale the dust or fine particles associated with it especially if it contaminated with a chemical agent. Prolonged skin contact with fuller's earth may cause skin irritation. Inhalation of dust or fine particles associated with it may lead to an irritation/inflammation of the respiratory tract.

Polymeric Sorbents. Several polymeric resins have been developed over the years for use in the decontamination of chemical weapons. One which is currently used by the U.S. Army in the M295 equipment decontamination kit is XE-348. XE-348 is a high surface area carbonized macroreticular styrene/divinylbenzene resin that is highly sorptive and will physically absorb liquid CW agents. By itself the XE-348 will not promote degradation of sorbed chemical agents, but can hold many times its weight of chemical agent. Polymeric sorbents such as XE-348 are typically blended with other polymeric sorbents that have been chemically modified in order to make them reactive towards the chemical agents and promote their degradation (CB-100354).

5.6.2 Reactive Sorbents

A reactive sorbent first absorbs the agent then chemically detoxifies the agent. Reactive sorbents have been prepared by soaking simple sorbents in alkaline solutions, effectively "loading" the matrix with caustic. Once absorbed into the sorbent matrix the agent encounters the alkaline medium, reacts with it, and is destroyed. Another approach for reactive sorbents is to prepare a polymeric material with reactive groups attached to the polymeric backbone. In this case the agent is sorbed by the polymeric matrix, encounters the reactive group, and is neutralized by it. One other approach is to prepare high surface area, nanoparticles of metal oxides such as magnesium oxide. Metals such as magnesium form basic oxides that readily react with chemical agents to quickly neutralize the agent.

A polymeric sorbent material was incorporated into nonwoven fiber pads for use as a personal decontamination kit to remove bulk agent from skin, clothing, and personal equipment, by wiping down the contaminated areas. The polymer used was a resin mixture (XE-555) developed by the Rohm & Haas Company. XE-555 consists of XE-348, XN-1010, and IRA-900. The XE-348 polymer is a high surface area carbonized macroreticular styrene/divinylbenzene resin that has a high sorptive capacity. XN-1010 is a strong-acid ion-exchange resin that promotes the degradation of the chemical agents. IRA-900 is a strong-base ion-exchange resin that also promotes the degradation of sorbed chemical agents. (CB-100354). Unfortunately, the production of the XE-555 resin by Rohm & Haas was ceased for financial purposes. The XE-555 resin mixture had a high capacity to absorb liquid chemical agents, and was lighter in weight than a liquid decontaminant of similar effectiveness. The XE-555 sorbent was a nontoxic, free-flowing solid material capable of absorbing liquid chemical agents into the micropores of its structure.

The most common application of the XE-555 resins was in the M291 skin decontamination kit. The kit consists of six nonwoven fiber pads filled with XE-555 material. The lightweight M291 kit is stored in one of the pockets of the soldier's Battle Dress Overgarment (BDO), and is capable of being used over a temperature range of -50°F to 120°F (2). The resin containing wipes are used to decontaminate the hands, face, ears, neck and other exposed skin of a soldier.

The XE-555 resins were made from a styrene/divinyl benzene copolymer and contained high surface area carbonized macroreticular styrene/divinylbenzene resin which was the sorptive resin, a strong acid cation-exchange resin (sulfonic acid groups), and a strong base anion-exchange resin (tetralkylammonium hydroxide groups). The resin (XE-555) rapidly absorbed the liquid agents, and then the reactive resins were used to promote hydrolysis of the absorbed agents.

In 1991- 1992, MSA Research Corporation investigated 12 different sorbent materials against the XE-555 polymeric mixture in an effort to find a replacement for XE-555. It was determined that the sorbent KVK-2536C retained HD, VX and thickened GD (TGD) more effectively than any of the other sorbents tested including XE-555. (CB-022340) KVK-2536C is a macroreticular ionic styrene polymer. (CB-022797) The KVK-2536C also had a better overall reactivity and decontamination efficacy than the XE-555. MSA Research corporation recommended additional testing be performed using sorbent mixtures in the development of an optimum decontamination sorbent for TGD, HD, and VX (CB-022340).

Other reactive polymeric sorbents have been developed for use in the decontamination of chemical agents, and have been compared against the XE-555 mixture for effectiveness. In a three-year study, Southern Research Institute investigated over 100 reactive sorbents in their ability to decontaminate and detoxify chemical agents. It was determined that a commercial poly(divinylbenzene) substrate sorbent, Jordi Gel™ (JG) impregnated with a reactant solution consisting of polyethyleneimine, sodium hydroxide and polyethylene glycol (PNP), and poly(divinylbenzene) substrate polymer (DVB) developed at Southern Research Institute impregnated with the PNP solution were at least as reactive as XE-555, and were good candidates to replace the XE-555 resin mixture (CB-100354).

In 1989 the Canadian Defence Research Establishment Suffield, Ralston, Alberta published a comparison of a Reactive Skin Decontamination (RSD) Lotion, the Canadian Decontaminating Mitt (active ingredient fuller's earth), and the U.S. Army M291 Skin Decontamination Kit (SDK) (active ingredient XE-555). It was determined that the Canadian lotion based system was almost as effective as the M291 kit, and superior to the fuller's earth containing mitt. It was also stated that additional work may result in improvements to the RSD lotion (CBCB-011530).

5.6.3 Catalytic Sorbents

Catalytic sorbents are similar to reactive sorbents in that both contain reactive sites that react with and detoxify the chemical agent. In the case of catalytic sorbents the reactive site is regenerated during detoxification of the agent while in the case of reactant sorbents the reactive group is rendered inert after reacting with the agent. Examples of catalytic sorbents are polyoxometalates sorbed into a sorbent polymeric matrix and polymeric materials containing reactive sites that are covalently bound to the polymer chain.

The Eastman Kodak Company investigated polymeric sorbents blended with catalysts and reactants in the decontamination of CW agent simulants during 1989-1990. It was determined that polymeric sorbent powders can be loaded with multiple catalysts/reactants in order to be effective against several agents. Eastman Kodak reported that their KMC-1 proprietary polymer (a cationic microgel utilizing a 50% loading of quaternized amines) mixed with 17% Oxone or 29% Chloramine-T was able to decompose or oxidize various H and G simulants. Incorporation of 7% sodium iodobenzoate (NaIBA), and 29% Oxone into the KMC-1 powder effectively hydrolyzed a VX simulant. The results for the KMC-1 mixtures were found to be more effective than XE-555, and Eastman Kodak recommended that various formulations be tested against actual chemical agents, and the effects of temperature and humidity be evaluated (CB-548319).

5.6.4 Current Applications

Sorbent technology has been employed for use in several skin and personal equipment decontamination kits by international forces. The Chemical Decontamination Glove mle, manufactured in France by Bachmann, consists of a mesh contained decontamination sorbent (e.g., fuller's earth) on one side and a sponge fabric on the other. The South African Decontamination Glove is similar to the French version, where the glove is lined with 200 grams of fuller's earth and is dabbed onto the contaminated surface in order to absorb the agents. Finally, the Yugolslav Army uses the LPD-M3 personnel decontamination kit, manufactured by Yugoimport SDA, consisting of a sorbent containing glove, to decontaminate skin and personal equipment.

Fuller's earth can also be used to contain a variety of chemical (both toxic and non-toxic) spills, until proper decontamination/detoxification materials are available. Examples of everyday uses of spill containment are the use of fuller's earth (kitty litter, Oil Dry™, etc.) at a vehicular accident scene by emergency response personnel to prevent the spread of fuel, motor oils, anti-freeze solutions or other hazardous materials from reaching sanitary sewers or water runoff areas and prevention of personnel from slipping on the slick surfaces and sustaining injury. Another example is the use of fuller's earth in a drum storage area where liquids are warehoused. If a drum should begin leaking, fuller's earth can be spread to minimize the amount of fluid that could be environmentally harmful while the contents of the drum are being transferred.

These techniques can be used should a container of a chemical agent be compromised and begin leaking. Fuller's earth can be used to absorb large quantities of the agent thereby preventing its spread and minimizing subsequent volatilization while emergency response teams apply a suitable detoxification agent.

Simple non-reactive sorbent polymers can also be used in a manner similar to fuller's earth in the containment of hazardous material spill containment. The cost for routine use may be prohibitive as compared to fuller's earth, however, there may be applications where a polymer such as XE-348 is better suited than fuller's earth.

Simple sorbents could also be used in a prophylactic manner when hazardous materials are being transferred from one point to another. Sufficient amounts of fuller's earth or XE-348 could be spread along the transportation route in case there should be a spill. If a spill were to occur, it would be a limited spill with the material being immediately absorbed into the sorbents reducing volatilization into the atmosphere and the area affected by the chemical spill. Should there not be a spill, the sorbents can be reclaimed for reuse at a later time.

5.6.5 Evaluation Results

Stabilized chlorine dioxide on synthetic calcium silicate has been demonstrated to kill common pathogenic microorganisms when activated to release free chlorine dioxide. The same material absorbs and destroys >90% of the mustard simulant, 2-chloroethyl ethylsulfide with one day of contact. Disopropyl fluorophosphate (GB simulant) is absorbed by this material with 10% destruction in 8 hr., 65% destruction in 5 days and 99.9+% destroyed in 15 days (CBIAC B170135).

Different types of Fullers Earth were compared for decontamination of chemical agents. Twenty-two fuller's earth materials were tested against liquid and vapor-phase chemical agents to determine the domestic availability of sorbent powder substitutes for Surry Fine. Twenty of the fuller's'earth materials demonstrated equal or better sorption properties (CBIAC B064597).

5.6.6 Technical Assessment

Sorbent technology is a promising approach to the decontamination of chemical agents. This technology is especially useful in the decontamination of skin and personnel equipment, where the agent must be removed quickly to limit the physiological effects on the soldier. The technology can also take advantage of the commercial developments of new and highly specific sorbent materials. Many of these materials are developed for analysis of ultra-trace levels of contaminants in complex matrices such as soils and natural waters. Some examples of new sorbent technologies include the use of nanotechnology to produce nanoparticulate magnesium oxide. Magnesium oxide is a basic oxide that can readily react with chemical agents producing non-toxic compounds with limited aqueous solubility. By preparing the magnesium as nanoparticles, the reactivity can be significantly increased due to high surface area of the material. Another novel sorbent based technology is the combination of dendritic polymers with immunoassay type reactants. This technology is one of the only sorbent technologies capable of decontaminating biological agents by binding the agents to the polymeric surface effectively making it non-reactive.

5.7 Mechanical Processes

Mechanical processes technology is a broad term used to describe any process that physically removes chemical or biological contamination from a surface. This technology encompasses a wide variety of separate technologies that all implement a mechanical process to remove contamination. Mechanical technology has the capability to physically remove the agent contamination, but cannot neutralize the agent by itself. Another separate technology must be employed to destroy the agent. The following sections describe four different processes that are either currently employed or could potentially be employed to decontaminate surfaces.

5.7.1 Pressurized Carbon Dioxide

Pressurized CO_2 cleaning is a process that involves the use of CO_2 to remove micron and submicron particulates and hydrocarbon based contamination from surfaces. The pressurized CO_2 cleaning process is based upon the expansion of either liquid or gaseous CO_2 through a small asymmetric venturi orifice. This expansion leads to the nucleation of small dry ice particles and a high velocity of gas stream. Upon impact with a surface, the dry ice particles remove the micron and submicron particulates through momentum transfer. Hydrocarbons are removed via a transient solvent mechanism. The high-velocity gas stream physically blows the contaminants away. The process is nondestructive, nonabrasive, residue-free, and leaves no chemical waste. Cleaning with CO_2 can be done via the following methods:

Snow Cleaning. Snow cleaning systems rely on the expansion of either gaseous or liquid CO_2. Cleaning is accomplished through a combination of momentum transfer and solvent action. The key component in the implementation of snow cleaning is the nozzle design. The output is a stream of snow, either high or low velocity, carried along by the gaseous CO_2. The presence of dry ice or snow flakes leads to the term "Snow Cleaning".

Two different commercial approaches to the implementation of snow cleaning technology exist. The first approach involves the generation of a high velocity stream of microscopic snow. The second approach uses a low velocity stream of large snowflakes. The high-velocity, small snow spray systems can remove both particulates and organic residues while the low velocity, large snowflake streams are capable of only removing particulates (no organic contamination removal). Large snowflake formation requires a liquid CO_2 source while the microscopic snow stream can be formed with either a liquid or gas CO_2 source.

Dry Ice Pellets. Pellet systems can be used to accelerate macroscopic dry ice pieces as a means of contamination removal. Contamination removal is accomplished by thermo mechanical impact shock. The dry ice particles are directed at high velocity towards the contaminated surface and upon impacting sublimes, converting from a solid into a gas. Thus, only the removed surface contaminant requires disposal. The key processes of a pellet system are the:

- Formation of the pellets of the desired size
- Maintenance of the pellets at the proper conditions
- Pellet feed rate
- Acceleration of the pellets by either mechanical methods or compressed gas
- Distribution of pellets on the item being cleaned.

5.7.1.1 Current Applications. Pressurized CO_2 cleaning is being used for numerous critical and non-critical cleaning applications in the optical, semiconductor, medical, research, surface science and analysis, and manufacturing communities. Generally, pellet systems are manufactured and used for material removal and usually only address cleaning situations when the object for cleaning can withstand the expected impact damage.

Pressurized CO_2 units are currently being employed in commercial cleaning industries to remove dirt and grease from sensitive equipment. Va-Tran Systems, Inc. of the U.S., manufactures the Sno Gun (SG-1), which is designed to remove contaminants as small as 0.1 micron from sensitive equipment. Applied Surface Technologies of the U.S., manufactures the Snow Motion, a fully automated CO_2 snow cleaning workstation. Cryo*Kinetics* of the U.S., manufactures the Model Delta V-1, a non-toxic, non-conductive, non-waste generating dry ice unit designed to clean contaminated surfaces. Cryo*Kinetics* is also currently employing CO_2 to disinfect biological agents. Recently, pressurized CO_2 has been used to clean the 400-inch Keck Telescope, the largest telescope in the world, located in Hawaii. In addition, universities have used dry ice snow systems to remove contamination from satellite assemblies.

5.7.1.2 Evaluation Results. Pressurized CO_2 units have been employed to remove dirt and grease from sensitive equipment in commercial industries. Although, actual cleaning efficiency numbers were not obtainable, pressurized CO_2 cleaning has proven to remove a wide range of contamination from sensitive equipment. CO_2 units have successfully cleaned optics, metals, circuit boards, and other pieces of sensitive equipment. However, no testing has been conducted to evaluate pressurized CO_2's effectiveness to decontaminate chemical or biological agents.

5.7.1.3 Technical Assessment. Pressurized CO_2 technology could potentially be employed to decontaminate sensitive equipment. Further research will be required in order to determine whether or not chemical agents can be removed utilizing CO_2. The effectiveness of pressurized CO_2 is based upon finding the optimal temperature and pressure, where the chemical agent would become soluble in CO_2. At this optimal temperature and pressure, pressurized CO_2 could prove to be a viable method to decontaminate sensitive equipment. However, this process will only remove the contamination, another technology will need to be employed to neutralize the agent.

5.7.2 Ultrasonic Cleaning

Ultrasonic cleaning uses ultrasonic energy to clean a wide variety of materials. Ultrasonic sound is sound transmitted at frequencies beyond the range of human hearing. When ultrasonic energy is introduced into a cleaning solution, the sound waves from the transducer radiate through the solution, causing alternating high and low pressures in the solution. During the low-pressure stage, millions of minute bubbles, or vacuum cavities, form and grow. During the subsequent high-pressure phase, the bubbles collapse, or "implode," releasing enormous amounts of energy. This process is called cavitation and is the foundation of ultrasonic cleaning.

Cavitation, shown in Figure 5.7.2, provides an intense scrubbing action that leads to unsurpassed cleaning speed and consistency when compared with simple soaking or immersion with agitation. The implosions occur in all directions, thus increasing the cleaning capabilities. Additionally, the bubbles are small enough to penetrate microscopic crevices.

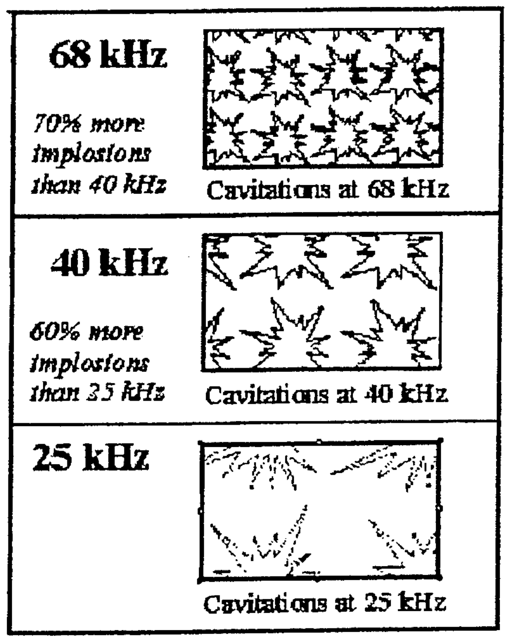


Figure 5.7.2. Cavitation Implosions at 25, 40, and 68 kz.

5.7.2.1 Current Applications. Ultrasonic technology is currently used in a wide variety of commercial applications. Ultrasonic cleaners are used to remove dirt, oil, and rust from medical instruments, electronics, optics, PC boards, and metals. Crest Ultrasonics, located in the U.S., manufactures the Optimum Console which is an ultrasonic cleaner available in three, four, and five wash stage station designs. The three-station system is a "wash-rinse-dry" system designed for most general cleaning applications. The four-station "wash-rinse-rinse-dry" system is ideal for precision cleaning applications at the microscopic level. The five-station "wash-wash-rinse-rinse-dry" is configured for semi-aqueous cleaning applications. All systems can be custom made for different frequencies. Master Sonics Corporation, located in the U.S., also manufactures a series of ultrasonic cleaners, which have been employed to clean a variety of sensitive equipment. Master Sonics' units have been employed by the aircraft industry to clean brake parts, generator components, actuators, shuttle valves, filters, wheels, and engine blades. In addition, Master Sonics has utilized ultrasonic technology to clean medical forceps and optical surfaces.

The Department of Energy's Y-12 nuclear weapons plant in Oak Ridge, Tennessee, employed ultrasonic cleaning with aqueous detergents to replace about 95% of the vapor degreasing with chlorinated solvents. Digital Equipment Corporation (DEC), located in Colorado Springs, Colorado, and Kaufbeuren, Bavaria, Germany, has replaced chlorofluorocarbon (CFC) cleaning systems at its facilities with ultrasonic cleaners. Ultrasonic cleaning has provided companies with acceptable cleaning efficiency ratings.

5.7.2.2 Evaluation Results. Ultrasonic technology has been employed to decontaminate sensitive equipment. Although, actual cleaning efficiency numbers were not obtainable, ultrasonic cleaners have proven to remove organic residues, inorganic scales, rust, oxides, carbon, dirt and grease from sensitive equipment in commercial industries. Ultrasonic cleaners have successfully cleaned optics, metals, circuit boards, and other pieces of sensitive equipment. However, no testing has been conducted to evaluate the effectiveness of ultrasonic cleaning to decontaminate chemical agents.

5.7.2.3 Technical Assessment. Ultrasonic cleaning could potentially be employed to decontaminate sensitive equipment. Further research will be required in order to determine the effectiveness of removing agents utilizing ultrasonic energy. Ultrasonic cleaning generally employs water as the cleaning liquid. However, decontaminants and other cleaning agents (i.e. neutral aqueous solutions, alkaline aqueous solutions, acidic aqueous solutions, ethyl lactate, alcohol, or acetone) could be added to facilitate decontamination and improve cleaning efficiency. The unique scrubbing action that ultrasonic cleaning provides coupled with it's cleaning diversity may serve as viable method for decontamination of sensitive equipment. However, this process will only remove the contamination, another technology will need to be employed to neutralize the chemical agent.

5.7.3 Water and Water Pressure

5.7.3.1 Water. Water is a key material for decontamination of chemical and biological agents. The G agents are highly susceptible to destruction by reaction with water via the chemical reaction termed hydrolysis. However, both VX and HD are less susceptible to destruction by hydrolysis and in some cases will form hydrolysis products that are almost as lethal as the original agent. To decontaminate agents such as VX and HD, different chemicals are added to the water, for example bleaches in water are used to decontaminate all chemical agents.

Water with the addition of detergents (e.g., alkyl sulfonates and quaternary ammonium compounds) is effective for the decontamination of surfaces and materials contaminated with chemical agents (and biological agents). Decontamination by detergents and soaps in water occurs predominantly by the physical removal or dilution of the chemical agent. Soap increases the dissolution of chemical agents in water. The use of soap and water for the physical removal of contaminants from skin and equipment will limit the spread of contamination. Also, for equipment, the removal of the bulk contamination will facilitate the decontamination process by weathering.

Soap and water (especially soap and hot water) also has the capability to neutralize agents to some extent by the chemical method of slow hydrolysis. Hydrolysis is limited due to the typically low solubility and slow rate of diffusion of agents in water.

Solutions of water with detergents containing perborates are effective in detoxifying nerve agents. Unless the pH is high enough, the hydrolysis products of V-agents may remain toxic in water solutions containing detergents without perborates. The hydrolysis rate for mustard agents in soapy water is slower than in clean water because the soap encapsulates the agent. However, the detergent in the water helps in the physical removal of mustard agents although the agent is not destroyed in the process.

The contaminated surfaces may be wiped or scrubbed with hot, soapy water. If possible, the item may be immersed in soapy water; however, the remaining water is contaminated by the chemical agent so precautions must be undertaken to prevent additional contamination. Chemical agents are not detoxified by the soapy water so the runoff water must be considered contaminated and could spread contamination. The wastewater from the water runoff must be collected and treated to detoxify the agents.

Natural waters, such as seawater also promote fast degradation of G agents via base catalyzed hydrolysis due to the relatively high pH (~8) of seawater.

5.7.3.2 Pressurized Water. Water sprayed at high pressures onto vehicles can effectively remove, but not necessarily destroy, chemical agents on the surface. Studies have demonstrated that agents can be removed from surfaces with water pressures $\leq$ 3000 psi. Removal of agents from surfaces is highly dependent upon the nature of the surfaces, i.e., surfaces which are flat and smooth can be more readily decontaminated than curved porous surfaces using water sprays. Other parameters which affect the effectiveness of water streams for decontamination are: pressure, temperature, angle of attack, traverse velocity, space between traverses, standoff distance, flow volume, and jet characteristics. It should also be noted that additives can be added to the water to improve the water jet characteristics. Likewise, water sprayed onto personnel using showers or other low-pressure delivery systems can be used to decontaminate skin. The use of soap to enhance dissolution of the agents will also aid in decontamination of the skin. Water can be used as a field expedient decontaminant for personnel and equipment, in this case, the vehicle or soldier is simply washed with available water.

High temperature saturated steam is also employed to remove chemical agents. Saturated steam is also used to remove grease and oil, as well as sterilizing, disinfecting, degreasing and degassing. Steam is efficient for cleaning surfaces before painting or other treatments, and will flush away poisons and chemicals, as well as dissolve resins and tars. It is ideal for de-icing applications, as well as killing algae or mildew.

It is important to note that using water to physically remove agent from surfaces does not mean that the agent has been detoxified. The G agents are relatively soluble in water and therefore will probably be destroyed, over time, via hydrolysis when washed off using water. However, agents such as VX and HD are not readily detoxified by water and can remain toxic for prolonged periods of time in a stagnant pool of water. For this reason, decontamination operations using water sprays should include the addition of a common decontaminant such as bleach to the runoff sump to destroy agent in the liquid run-off.

5.7.3.3 Current Applications. Water is currently used to physically remove agents from surfaces by pressurized sprays. Water can also be used as steam to remove and destroy chemical agents. Pressurized washing also helps to remove any dirt or mud which may contain agent. Karcher manufactures a series of pressurized water systems. Karcher's HDS 1200 EK and the SCS 1200 DE are pressurized steam cleaners that employ pressurized cold or hot water, steam or dry steam to decontaminate exterior equipment. Cristanini of Italy, manufactures the C90-120-2 MIL Decontamination System which is designed for the decontamination of exterior equipment, personnel, and large areas. The major drawback to pressurized water decontamination is that the agent is not readily destroyed but only physically transported from the surface of a vehicle to a sump. However, bleach or other chemicals can be added to water for use by the decontamination system to chemically attack and destroy the agents. These solutions are covered under the strong base and oxidizer technologies.

5.7.3.4 Evaluation Results. Karcher, Hoje Pump 400/70 was used to decontaminate three different simulants. The simulants used were diethyl malonate (DM), thickened diethyl malonate (TDM), and thickened diethyl sebacate (TDS). 97% of the DM and TDM were decontaminated using cold water.

90% of the TDS was decontaminated with cold water. Using steam, <96% of DM, TDM, and TDS were decontaminated (CBIAC AD-D750186).

Alkyd- and polyurethane painted metal and canvas substrates were contaminated with 9.3, 11.5, and 4.8 g/m^2 of thickened GD, THD and VX agents, respectively. After 1 hour of weathering the surfaces were hasty decontaminated using cold water, hot water, cold soapy water, hot soapy water, or steam. The overall effectiveness for all agents and substrates was determined to be steam>hot water>hot soapy water>cold soapy water>cold water (CBIAC AD- B170021). A review of the effectiveness of water streams for physical removal of contamination from combat vehicles has been completed. The effect of non-reactive additives and the use of hot and cold water, as well as brackish water, is also included (CBIAC AD-B154567).

5.7.3.5 Technical Assessment. Water can be used to decontaminate vehicles, equipment, personal, and personnel equipment with or without added decontaminants. Through the use of high pressure (<3000 psi) and/or temperature (steam), agents can be physically removed from surfaces to a large extent. However, removal of agent from cracks, crevices, and oblique/occluded surfaces remains difficult. This technology is effective for quick knockdown of high concentrations of agent from equipment and personnel but some other technology or process may be required to neutralize the agent to safe levels. The destruction of HD and VX is enhanced by the addition of reactive species such as bleaches that oxidize the agents to non-toxic substances. The equipment that utilizes pressurized water should include a scrubbing apparatus to increase the decontamination efficiency.

5.7.4 Reverse Osmosis

When a dilute solution of a substance (e.g., 1% sodium chloride in water) and a more concentrated solution (10% sodium chloride in water) are separated by a semi-permeable membrane, the solvent (water in this example) from the dilute solution will diffuse through the membrane into the more concentrated solution. This naturally occurring process is called osmosis. When osmosis reaches a state of equilibrium, a point where there is no longer a net change in the volumes of the two solutions, the difference in pressure between the two solutions is known as osmotic pressure.

Only the solvent passes through the membrane. The molecules of sodium chloride do not travel through the membrane because the membrane will not pass them. This is why the membrane is called a semi-permeable membrane. If it were a permeable membrane, then both solvent and solute (sodium chloride) molecules would pass through. If the membrane were not permeable, neither the solvent nor the solute molecules would move through the membrane in either direction, unless a hole or a tear was present in the membrane.

Any physical pressure (e.g. from a pump) greater than the osmotic pressure applied to the side containing the concentrated solution, will cause the solvent (again, water in this case) to diffuse through the semi-permeable membrane and into the lower concentrated solution. The direction of this diffusion is opposite that of osmosis, and is hence called reverse osmosis (RO).

RO can therefore be employed to purify, for example, water containing one or more impurities. In a simplified example, contaminated water can be poured into a tube that has a semi-permeable membrane affixed to one end. An o-ring sealed, piston-type plunger is then inserted into the tube and a force of 30 pounds per square inch (psi) is applied to the exposed end of the plunger. After a short period of time, drops of water (minus the impurities) begin to appear on the previously dry, exterior side of the membrane. As more water passes through the membrane, the rate at which it passes through diminishes until it stops because the osmotic pressure has matched the pressure being applied to the solution by the plunger. In order to purify more water, a greater force (pressure) must be applied to the plunger in order to overcome the new osmotic pressure equilibrium.

5.7.4.1 Current Applications

5.7.4.1.1 Non-Military Applications. Large-scale water purification using RO technology has been used for many years in the desalinization of salt water from the oceans to provide potable water to coastal communities. RO has also been used to purify and desalinate irrigation water for use in greenhouse and hydroponic farming. In one case, a farmer in Florida was able to increase his production of European cucumbers from about 4000 per day to 7000 per day after changing from a contaminated surface water source to a brackish groundwater source that was subjected to treatment by RO. RO is also effective in the removal of organic and inorganic toxic compounds such as trihalomethanes, its precursors, agricultural chemicals (herbicides and insecticides), arsenic, barium and lead. Reversed osmosis is also used in the pharmaceutical industry to provide ultra high purity water in the manufacture of pharmaceuticals.

5.7.4.1.2 Current Military Applications. The U.S. Army has several different Reversed Osmosis Water Purification Unit (ROWPU) models that can be used depending upon the number of gallons of purified water needed per hour. ROPWU generation capacities range from 600 gallons per hour (GPH) to 150,000 gallons per day (GPD). All effectively remove 99.9 percent of NBC contaminants present in the water introduced into the ROPWU either alone or in combination with post-treatment units such as specialized, application specific filters.

The self contained ROWPUs are capable of operating in the widest variety of locations, climates, and conditions. All that is needed is a source of water. Test kits (M272 Water Testing Kit-Chemical Agents) are available for testing water supplies for chemical agent contamination, and if nuclear weapon contamination is suspected, the radioactivity can be measured using the AN/PDR 27 Radiac Meter. In the case of infectious organisms and toxins, the ROWPUs employed by the U.S. Army, are capable of removing or destroying any that were present in raw water sources.

5.7.4.2 Evaluation Results. In an NBC environment, the ROWPU can decontaminate water up to a level of 99 percent. The addition of a post-treatment unit must be used in order to remove 99.9 percent of the NBC contaminants present in the untreated water.

In a nuclear weapons (NW) environment, the ROWPU characteristics are given below:

Agent	Percent Removed
Iodine	95.5
Cesium	98.8
Strontium	99.7

The remainder of the NW agents are removed from the water through the use of a nuclear cylinder in the post-treatment section.

In a chemical weapons (CW) environment, the ROWPU characteristics are given below:

Agent	Percent Removed
GB	99.1
GD	99.7
VX	99.9
BZ	99.9

The remainder of the CW agents are removed from the water through the use of a chemical cylinder in the post-treatment section.

In a biological weapons (BW) environment, the ROWPU will remove large amounts of biological agents. There are no established RO characteristics for BW agents. Any BW agents that are not removed by the ROWPU will be eliminated by the residual chlorine present in the purified water.

5.7.4.3 Technical Assessment. Reverse osmosis is a proven, effective technology for the purification of water from various sources. RO has been used for almost four decades for the desalinization of water in coastal and tropical regions in order to provide for the water needs of the population. There has been a demonstrated ability of RO to remove virtually all contaminants present in a raw water source. In addition, membrane and filtration technology is continually improving, resulting in RO systems that are better able to remove organic and inorganic compounds, bacteria, viruses, toxins, and smaller particulate materials. Reverse osmosis is an effective technology for the decontamination and detoxification of large quantities of water exposed to NBC agents.

5.8 Weathering Technology

Weathering describes a passive form of decontamination whereby natural sources of heat and UV radiation (sunlight), water (precipitation), and wind combine to decontaminate a vehicle, a piece of equipment, large structures, and large areas of terrain. During the weathering process decontamination of chemical agents occurs by evaporation of the agent (physical removal) or destruction of agents by hydrolysis or photolysis (chemical reaction). The effectiveness of weathering for decontamination is very dependent on the persistency of the chemical agent. Some of the factors that affect the persistency of chemical agents are weather (wind speed, atmospheric stability, precipitation), terrain, vegetation, soil, method of dissemination, type of agent, type of surface, and materials onto which the agent is deposited. Of these factors, the weather (i.e., wind, ambient temperature, humidity, precipitation, and atmospheric stability) is one of the most important factors affecting agent persistency. Wind speed significantly influences the persistency of chemical agents. High winds rapidly disperse chemical agent aerosols and vapors, thereby decreasing their effective coverage over the target time of exposure to an agent. Temperature also plays a major role in the persistency of liquid agents. The higher the temperature the faster the agent will evaporate. In hot conditions with no wind, significant vapor hazards can occur and decontamination by weathering is not as effective. However, the combination of high temperatures and moderate to high winds can be effective in decontamination.

5.8.1 Current Applications

Decontamination by weathering is recommended by FM 3-8 for roads, roofs, buildings, machinery, vehicles, terrain (beaches, deserts, undergrowth and tall grass), boxes, crates, and wood surfaces. Aircraft decontamination has been shown to be effective by simply flying the aircraft, which enhances weathering decontamination.

5.8.2 Evaluation Results

A study to determine the time required for decontamination of various surfaces via natural weathering was conducted by R.A. Crochet, entitled "Comparison testing of chemical agents and simulants on polyurethane painted surfaces" (Report #ERDEC-CR-018 (1993)). Investigation into the decontamination of roadbed material showed that by increasing the temperature of asphalt from 21°C to 34°C, the half-life of TGD was reduced from 73 minutes to 34 minutes. Results also showed that TGD exhibited longer half-lives on alkyd-painted surfaces than bare metal and polyurethane painted surfaces. It was concluded that by increasing the surface temperature, the effectiveness of decontamination increases due to the increased evaporation rate of the agent. The surface type was also determined to have a great effect on the half-life of the agent.

The effect of flight on the removal of chemical agent contamination from aircraft was studied. Many of the conclusions were classified, however, unclassified conclusions were:

- Surface paint type plays a major role in the level of agent reduction from aircraft flight
- The high speed airstream causes surface droplet breakup enhancing agent loss due to evaporation
- Forty minutes of weathering at 24°C and 0 wind speed is effective in removing at least 96% HD on polyurethane painted surfaces, GD and TGD on acrylic and polyurethane painted surfaces
- Thickened agents are not effectively decontaminated
- Forty five minutes of exposure to an airstream at 148 knots does not result in the complete removal of VX from acrylic and polyurethane painted surfaces
- Results indicate that simply allowing for 30 minutes of weathering without flight reduces the levels of GD and TGD contamination 96 and 99 percent, respectively, indicating that any significant benefit from flying GD or TGD contaminated aircraft as a means of decontamination would only be realized if the flying occurred quickly, i.e., sooner than 30 minutes after initial contamination.

Tests were conducted on alkyd and CARC painted metal surfaces to compare natural weathering to agent removal at elevated temperatures. The chemicals used for this study were THD and its candidate simulant, thickened dimethyl adipate (TDMA), TGD and its candidate simulant, thickened triethylphosphae (TTEP), and the V agent, EA 1699 and its candidate simulant diethyl pimelate (DEPIM). Results are presented in Table 5.8.2-1 and Table 5.8.2-2.

Table 5.8.2-1. Decontamination Enhancement of Heat Treatment Compared to Natural Weathering for Paint

Chemical	Decontamination Enhancement (Percent)	
	Alkyd Paint	CARC (polyurethane) Paint
THD	38	59
TDMA	25	54
EA1699	9.5	57
DEPIM	6	96
TGD	N/A	53
TTEP	32	27

Table 5.8.2-2. Comparison of Surface and Sub-Surface Contamination After Heat Treatment and Natural Aging of Paint

Chemical	Alkyl Paint		CARC (Polyurethane) Paint	
	% Reduction, Surface	% Reduction, Sub-Surface	% Reduction, Surface	% Reduction, Sub-Surface
THD	63	17	15	Not Absorbed
TTEP	50	4	29	Not Absorbed
EA1699	None on Surface	11	29	Increased by 12
DEPIM	None on Surface	11	20	0

This study showed that the combination of weathering and thermal treatment removes or destroys significant amount of chemical agents from the painted surfaces. Thermal enhanced decontamination of CARC (polyurethane) paint has the greatest effect on the surface concentration of agents.

5.8.3 Technical Assessment

Because of the slow nature of weathering it is not generally considered a primary form of decontamination. The one exception to this is decontamination of large ship exteriors where ready exposure to the alkaline seawater (pH = 8) and strong sunlight make weathering a viable mode for decontamination of large exposed areas of ships. However, under the best of conditions, decontamination by weathering is never as efficient as decontamination by direct application of decontaminant solutions to surfaces. However, decontamination using weathering of non-critical areas of operation can be considered a viable option for wide area decontamination. In this scenario decontamination of large areas of land or unused buildings which were contaminated with persistent agents such as VX or HD could be allowed to sit idle. Natural processes such as rain and sunlight would effectively decontaminate these areas. In the case of large areas of land there may have to be some steps taken to avoid spreading contamination in dust blown by the wind. One possible approach would be to wet down the contaminated ground each day until the contamination has been destroyed by the combination of wind, sunlight, and water.

5.9 Directed Energy

5.9.1 Plasmas

Plasmas offer the possibility of a dry, nondestructive means of decontamination. Plasmas are energetic, often reactive, ionized gases capable of conducting electrical current. Plasmas are used extensively by the microelectronics and magnetic storage industry to clean, etch, and form thin film deposits on surfaces. Energetic electron impact in the plasma leads to excitation, dissociation, and further ionization of molecules, yielding reactive metastables, radicals and ions. Oxygen containing plasmas readily oxidize many organic compounds, including chemical agents, and can chemically convert many inorganic compounds. Plasmas can also be used to decontaminate biological agents. In addition to the chemical action provided by oxygen radicals and ions, the plasma also emits ultraviolet radiation that can destroy many biological agents as well as enhance the chemical reaction rate. Low-pressure plasmas are also known as "cold" plasmas and are used for cleaning and treating surfaces ranging from angioplasty balloon catheters to electronic circuit boards and plastic bumpers for automobiles (http://clean.rti.org/pl_gen.htm). Low-pressure plasmas have also been used for medical equipment sterilization. Plasmas can also be formed and maintained at atmospheric pressure by application of a sufficient electric field. Atmospheric pressure plasmas can be non-thermal (i.e. "cold") or thermal (i.e. "hot"). Traditional cold atmospheric pressure plasmas, such as the corona discharge and dielectric barrier or silent discharge, are highly non-uniform and are typically used for volume processing of gaseous effluents or as ozone generators. Emerging cold atmospheric pressure technologies include the Atmospheric Pressure Plasma Jet (APPJ) and the One Atmosphere Uniform Glow Discharge Plasma (OAUGDP). These devices produce uniform plasmas which, in the case of oxygen containing plasmas, favors the preferable production of atomic oxygen over ozone. Hot atmospheric pressure plasmas, such as dc arc jets and radio frequency (rf) plasma torches, are typically several thousand degrees Kelvin. Common industrial applications of plasma torches include cutting and welding of metals.

Plasmas are typically generated and maintained at reduced pressure by capacitively-coupled electrodes placed inside a vacuum vessel and driven at frequencies ranging from dc to rf, by inductively-coupled coils surrounding a dielectric vessel and driven at rf or by applying microwave power into a vessel through waveguides. Low-pressure plasmas could be used to clean items contaminated with chem/bio warfare agents, provided that the item can fit into the vacuum chamber and will not be damaged by the low pressure or exposure to a rf or microwave field. Plasma decontamination procedures have several potential advantages over the current state-of-the-art decontamination technologies. First, the plasma fills the volume exposed to the applied field and thus will simultaneously clean the entire surface. The plasma will readily penetrate porous surfaces and clean complex shapes and blind holes. Second, there will be little or no waste produced, as the plasma will decompose the agent to benign, typically gaseous, byproducts. The mechanism of this chemical decomposition is complex and involves several different interactions. Ion bombardment of the surface causes surface heating, evaporation, and direct decomposition of surface contamination. Collisions of volatilized agent molecules with reactive species in the plasma such as atomic oxygen and various excited and/or ionic forms of atomic and molecular oxygen cause additional decomposition/oxidation. Ultraviolet light produced by the plasma initiates photochemical reactions that contribute to the decomposition and possible polymerization of the agent. Third, large amounts of water and decontaminates will not be required. Operation of a plasma system should only require electrical generation and small amounts of gases, greatly reducing the logistic burden of decontamination. A potential disadvantage of a plasma system is that the generation of ozone and the ion bombardment of the surface of the item being decontaminated can modify or degrade the surface. With proper control of the plasma, this modification and/or degradation will be insignificant as has been observed in other industrial treatment applications. Also, surfaces that are well shielded from rf radiation, such as the interiors of metal cases, will not be exposed to as large fluxes of reactive species as will exterior surfaces, reducing the decontamination rate on these surfaces. Of course these interior surfaces will most likely not have been exposed to as large levels of agents as exterior surfaces, so this aspect may not be of major concern.

An alternative to the use of low-pressure plasmas for decontaminating surfaces, is the use of atmospheric pressure discharges. This approach does not require a vacuum chamber or associated equipment. The traditional cold atmospheric pressure discharges, corona and dielectric barrier discharges, are highly non-uniform plasmas operating at high voltage and low current. Coronas form in highly inhomogeneous regions of an electric field. Typically a corona will form in the strong electric field close to a sharp corner, point or edge on an electrode. As the electrons and positive ions recombine, ultra violet light is emitted. Similar to a low-pressure discharge, the ultra-violet light combined with reactive ions, ozone, atomic oxygen and electrons, create a highly reactive environment conducive to the breakdown of chemical agents. Small objects that can be brought into the corona region can be decontaminated by chemical conversion of the agent. Also, agent that can be volatilized from a contaminated surface can be drawn through a corona discharge and decomposed. Corona discharges are used commercially to generate ozone for domestic water purification. This technology could also be applied to the decontamination of wastewater generated during conventional decontamination procedures. The dielectric barrier discharge, another atmospheric pressure plasma, consists of many short-lived micro-discharges distributed randomly in space and time between two electrodes, at least one of which is covered by a dielectric material. Similar to corona, the dielectric barrier discharge is best suited to gaseous effluent processing and ozone generation. (http://www.eng.tau.ac.il/Pages/Inter/edp_lab/index.html)

New and emerging cold atmospheric pressure plasma technologies producing uniform discharges may offer significant advantages over the above traditional cold discharges. The uniform nature of these discharges provides a continuous source of energetic electrons to dissociate O_2 and O_3, generating large concentrations of the highly reactive atomic oxygen while maintaining the less desirable ozone at much lower levels. These reactive species can then be "blown" onto a surface where they can react with the contaminates. This eliminates not only the potential for damage from exposure to a vacuum, but also the ion/electron bombardment damage potential of low-pressure discharges, since ions and electrons quickly recombine at the high collisionality associated with atmospheric pressure. The OAUGDP requires dielectric electrode covers, similar to a dielectric barrier device, and is driven at audio frequency, while the APPJ is driven at higher rf frequencies and requires no dielectric electrode cover. Both devices easily produce a uniform discharge using a helium feedgas. For decontamination applications, a small amount of reactive gas, such as oxygen, is added to the helium carrier gas. The OAUGDP operates at a much lower plasma power density than the APPJ, by nearly a factor of 1000, allowing it to operate closer to ambient temperatures. Although the APPJ produces higher temperatures, these temperatures can be maintained in an acceptable range for most decontamination applications (e.g. 50-300°C) and produce a synergistic effect by increasing reaction rates. Furthermore, it is inferred that the OAUGDP produces much lower fluxes of reactive species as a result of this lower power density. The use of a helium carrier gas may be acceptable in a closed recirculating system suitable for decontamination of small personal gear and sensitive equipment. However, excessive consumption of containerized gases presents a significant drawback for field operations. Stringent logistical requirements almost necessitates that atmospheric pressure discharges be fed predominately with air or other readily available feedgases, such as nitrogen or steam, in open systems used in the field for interior/exterior decontamination. The OAUGDP can be fed with air instead of helium, while APPJ technology is being developed for air feed.

Hot atmospheric pressure plasmas may also prove useful as a decontamination technology. DC arc jets, rf plasma torches and laser induced plasmas can obtain temperatures on the order of 10,000°C, however, the temperature of the surface to be decontaminated can be made much lower through limited exposure time, increased standoff distance, and/or co-injection of cooling gases. Hot atmospheric pressure plasmas could be used for relatively quick decontamination of equipment and large areas that can withstand momentary exposure to the high temperatures of the plasma. Use of hot atmospheric pressure plasmas for decontamination of metal equipment and exteriors of some vehicles (land, air, and water) and facility infrastructure is most likely. Another application for hot plasmas is decomposition of drifting aerosol and vapor clouds. The U.S. Air Force is investigating the possibility of using high power pulsed lasers to generate short duration atmospheric plasmas that would destroy chemical and biological clouds. The mechanism of destruction would be a combination of direct absorption of the laser radiation, heating of the ambient air, generation of ions, radicals, ozone, and ultra violet radiation in the resulting super heated plasma.

5.9.1.1 Current Applications. The industrial applications for plasmas are numerous. The semi-conductor industry uses plasmas for the processing of silicon wafers to make integrated circuits, performing steps such as etching, deposition, ashing, and cleaning. The electronics industry uses plasmas for cleaning electrical contacts and components. Manufactures of plastic products use plasmas, usually oxygen, to clean and chemically modify the surface of plastics to improve the adhesion of paints and adhesives. Plasmas can even be used to modify the surface of Teflon so that it can be painted or used with adhesives as well. Corona discharges are also used by the plastics industry to clean and modify the surface of plastic products. In general, however, reduced pressure plasma processes have provided better quality control. Corona and dielectric barrier discharges are also used for the generation of ozone and ultraviolet light for the purification of domestic water for consumption and for use in swimming pools (http://clean.rti.org/pl_gen.htm), (http://www.hydroponics.com/products/hydropure.html). Plasma torches are used for cutting and welding of metals as well as for applying coatings.

5.9.1.2 Evaluation of Results. Low-pressure plasma is quickly replacing prolonged exposure to ethylene oxide as the industry standard for sterilization of medical instruments. Johnson & Johnson commercialized a hydrogen peroxide sterilization chamber on the market since 1991, which kills spores in about a one hour cycle time, has good material compatibility including moisture and heat sensitive items, and only requires an electrical outlet for installation (i.e. no special ventilation or piping required). Such a unit may be suitable for chemical decontamination as well with little or no modification.

One investigation of the use of a corona discharge in air for the decontamination of painted metals and of air reports encouraging results for the decomposition of dimethy methylphosphonate (DMMP). DMMP samples placed on military specification paints were evaporated and decomposed from the surface in less than one minute using a six-needle corona discharge, compared to 47 minutes for natural evaporation to take place. Decontamination of DMMP in air streams using the same six-needle corona discharge also proved to be very effective. Based on this work, it was concluded that corona discharges were better suited for air purification and decontamination of small objects, than for wide area decontamination (DTIC AD-B092 072). Several other groups have also reported positive results using corona discharges in the form of reaction chambers, hand-held flares, wands, and blankets. However the most promising application of corona and dielectric barrier discharges appears to be in the volume processing of gaseous effluents and as ozone generators for the treatment of liquid effluents.

Results have also been reported on some of the emerging atmospheric pressure plasma technologies. Research by the University of Tennessee on the OAUGDP has resulted in a one log reduction time on the order of one minute for anthrax surrogate spores at near ambient temperatures. However, these results were obtained by placing the spore samples between two closely spaced electrodes, greatly restricting the range of surfaces that can be treated in this manner. APPJ results obtained by Los Alamos National Laboratory researchers places this one log reduction time at ~4 seconds at 175°C, ten times faster than hot gas at this temperature, and ~12 seconds at 75°C. These results were obtained about 0.5 cm downstream from the APPJ nozzle, making it possible to decontamination all accessible surfaces. Active research is aimed at increasing this standoff distance while maintaining an acceptable level of decontamination. Results obtained on CW simulants using the APPJ, as well as preliminary investigations on VX conducted at ECBC, also look promising.

Texas Tech University has demonstrated the use of a dc arc jet for destruction of anthrax surrogate spores. They propose to develop a vehicle driven system that can decontaminate roads and runways by exposing them to temperatures on the order of 500°C, which would allow the vehicle to be driven at speeds on the order of 1-5 mph. Similar systems could be developed for large area decontamination of terrain and structures that can withstand these high temperatures. They also plan to investigate the effect of the arcjet on CW simulants.

5.9.1.3 Technical Assessment. Oxygen containing electrical discharges are highly reactive environments conducive to the rapid oxidative breakdown of chemical and biological agents. They are particularly attractive because they produce little to no waste, require no hazardous chemicals (the highly oxidative and reactive environment is created from non-hazardous gases and exists only when an electric field is applied) and should work well on most biological and chemical agents. Low-pressure plasma based systems are well suited to the decontamination of small items with complex and porous surfaces. Equipment such as personal gear, including clothing and small arms could rapidly be cleaned in a low pressure plasma because the ionized gas is ubiquitous within the chamber. Thus, the plasma would simultaneously clean individual fibers in fabrics and any blind crevices or slots in equipment including rough and porous surfaces. Small arms could also be cleaned even for parts that are difficult to reach with decontamination sprays and impossible to reach with blotters. Corona discharge systems are particularly well suited for adaptation to the decontamination of air streams and wastewater treatment. APPJ technology may prove useful for decontamination of small sensitive items in a closed system capable of recirculating helium or other inert gases. It may also prove useful for exterior and interior surfaces, provided that a readily available gas, such as air, can replace helium as a carrier of small quantities of reactive gases. Hot atmospheric pressure plasmas may be suitable for decontamination of large areas capable of sustaining high temperatures for short periods of time, owing to its relatively short processing time.

5.9.2 Gamma Irradiation

Gamma rays are short wavelength electromagnetic waves emitted by certain radioactive isotopes such as cobalt 60 (60 Co) and cesium 137 (137 Cs). Gamma rays are highly energetic and have sufficient energy to cause ionization of certain classes of molecules and are therefore, classified as ionizing radiation. Gamma rays cannot break apart the nucleus of an atom, and therefore when absorbed, do not make the absorbing molecule radioactive. When living cells are exposed to gamma radiation ionization, molecules necessary for life, such as DNA and RNA, are denatured along with other necessary proteins, resulting in death of the exposed cells.

Gamma irradiation has been widely used for sterilization of medical and pharmaceutical supplies and foods. Gamma irradiation, for nearly all foods, is common practice in Europe. In the U.S., gamma irradiation used to kill insects in grains and bacteria and parasites in some meats. Because gamma radiation is does not harm plastics and fabrics, it is well suited for the decontamination of clothing and protective gear in a biologically contaminated theatre. Food and water supplies and possibly breathing air could also be irradiated to insure sterilization. Because the radiation from the gamma source is hazardous to humans, the irradiation must be done in a special chamber with continuous monitoring controls. (http://www.eatright.ort/airradi.html)

5.9.2.1 Current Applications. Current applications for gamma sources that are related to the destruction/decontamination of chemical and biological agents are the sterilization of foods, surgical, and pharmaceutical equipment. Gamma irradiation is used for sterilization during processing of most European foods and several foods in the U.S. Gamma irradiation is used to kill insects in grains, bacterial on meats, produce and in dairy products, and parasites in meats.

5.9.2.2 Technical Assessment. Gamma irradiation is an effective technique for disinfecting many kinds of bacteria on and in foods and in water. It has been used safely and effectively for many years in Europe and in the U.S. Its powerful proven anti-bacterial action, along with its deep penetration of materials, makes it a potentially effective tool for the decontaminating biological agents on equipment and in food supplies. It may also be effective at breaking down or initiating decomposition of chemical agents. Testing however is required to validate its effects on actual bacterial and viral agents, spores and toxins. Effective doses for decontamination of different agents and materials will also have to be determined. Testing for by-product effects caused by irradiating chemical agents is also required. It may be that irradiation initiates reactions that do not fully destroy the toxic properties of the chemicals. In the case of biotoxins this might be an important concern, as these are not living organisms, gamma irradiation may not destroy, or alter the toxicity of the toxin.

Gamma irradiation could prove very effective for decontamination of personal gear and small equipment. Because of its superb penetration through equipment, it might allow decontamination of areas difficult to clean by other means available today. Also, there would be no waste produced and little or no logistical support required. However, gamma radiation is toxic to humans and requires appropriate shielding for the source as well as the materials being treated during the decontamination process. The amount of shielding required, and the safety requirements needed for the proper use and transport of the gamma source may be restrictive.

5.10 Biological Processes

5.10.2 Bioremediation by Fungus

Fungus is a member of the kingdom (Fungi) which consists of non-sporulating organisms that live as parasites, symbionts, or saprophytes. Most fungi are multi-cellular, they consist of slender cottony filaments or hyphae. Fungi help decompose organic matter. They are also a valuable a source of antibiotics, vitamins, and various industrial chemicals and are valuable for their role in fermentation.

White Rot Fungus has been reported to be able to degrade a wide variety of organopollutants including the predominant conventional explosives TNT, RDX, and HMX. In addition, it has the potential to degrade other materials such as DDT, PAH, PCB, and PCP. White Rot Fungus achieves degradation of these materials by using its lignin-degrading or wood-rotting enzyme system. The optimum temperature for biodegradation with lignin-degrading fungus ranges from 30°C to 38°C (86°F to 100°F). The heat of the biodegradation reaction will help to maintain the temperature of the process near the optimum. White Rot Fungus has been tested using two different treatments. The first involved a bioreactor while the second treatment configuration took place in situ. (http://www.frtr.gov/matrix/section4/4_3.html)

5.10.2.1 Current Applications. Degradation of TNT in the lab using pure cultures has been successful, however, the difficulty of using this technology for full-scale remediation increases due to a number of factors. These factors include competition from native bacterial populations, toxicity inhibition, chemical sorption, and the inability to meet risk-based cleanup levels. High TNT or PCP concentrations in soil also can inhibit growth of white rot fungus. A study suggested that one particular species of white rot was incapable of growing in soils contaminated with 20 ppm or more of TNT. In addition, some reports indicate that TNT losses reported in white rot fungus studies can be attributed to adsorption onto the fungus and soil amendments, such as corncobs and straw, rather than actual destruction of TNT. (http://www.frtr.gov/matrix/section4/4_3.html)

There are several factors that are widely believed to optimize the viability and potential of white rot fungus. These factors include a nitrogen concentration of between 2 and 4 mM, high concentrations of oxygen, pH of about 4.5, and a moisture content of approximately 40-45%. White Rot Fungus is being used at the following sites for remediation:

Site Name	Summary	Beginning Levels	Levels Attained	Costs
Letterkenny AD Chambersburg, PA	Pilot-scale demonstration using PCP-treated ammunition boxes in less than ideal conditions.	425 ppm of PCB	30% removal but 80% removal in lab	NA
Brookhaven Wood Preserving, MA	White rot fungi to treat chlorinated VOCs and PAHs. Treatability Study in 1991. Full demo in 1993.	PCP 700 ppm	89% PCP removal 70% PAH removal	NA

(http://www.frtr.gov/matrix/section4/4_3.html)

5.10.2.2 Evaluation Results

5.10.2.2.1 Degradation of 2,4,6-Trinitrotoluene (TNT) by White Rot Fungus. Initial studies have demonstrated that White Rot Fungi are capable of degrading and detoxifying TNT under aerobic conditions in non-ligninolytic liquid medium. Ensuing research has been conducted to examine the effect of growth substrates, pH, incubation temperature, and TNT concentration on the amount of TNT degradation. The decrease of TNT concentration was determined using high performance liquid chromatography and 14C-labelled TNT. Detoxification was measured by the Salmonella/microsome mutagenicity assay.

The addition of starch (1% w/w) to the media was critical to the growth of the fungus as well as the detoxification of the TNT. *Phanerochaete chrysosporium* incubated at 37°C or 25°C had similar detoxification and degradation results. The fungi, *P.chrysospium and P. sordida*, grow best at a pH levels of 4 and 5. Also, at concentrations up to 92 mg/L fungi were able to grow and detoxify TNT most effectively.

5.10.2.2.2 Degradation of DCB, TCB, and HCB by White Rot Fungus. A study was performed demonstrating the ability of White Rot Fungus *Phanerochaete chrysosporium* to degrade three model polychlorinated biphenyl (PCB) congeners. These PCBs included 4,4'-dichlorobiphenyl (DCB), 3,3',4,4'-tetrachlorobiphenyl (TCB), 2,2',4,4',5,5'-hexachlorobiphenyl (HCB). (http://bob.soils.wisc.edu/soils/hickey/fungab.html)

After 28 days of incubation of *Phanerochaete chrysosporium* with the three model polychlorinated biphenyls, extensive degradation of the DCB including 11% mineralization was examined. TCB and HCB, however, showed negligible mineralization and little evidence of significant degradation. (http://bob.soils.wisc.edu/soils/hickey/fungab.html)

5.10.2.2.3 Degradation of Aromatic Alcohols by Filamentous Fungus *Penicillium simplicissium.* A novel type of flavoprotein aromatic alcohol oxidase was discovered. It was isolated from the filamentous fungus *Penicillium simplicissium.* The enzyme, vanillyl-alcohol oxidase (VAO) was involved in the degradation of phenolic alkylethers. The VAO gene has been cloned and solved for crystal structure. This will allow future protein engineering in order to redesign the catalytic performance. (http://gcg.tran.wau.nl/local/Biochem/wvb/vao1.htm)

This technology has been known for approximately 20 years with very few, if any, commercial applications. A pilot-scale treatability study was conducted using White Rot Fungus at a former ordnance open burn/open detonation area at Site D, Naval Submarine Base, Bangor, Washington. Initial TNT concentrations of 1,844 ppm were degraded to 1,267 ppm in 30 days and 1,087 ppm in 120 days. The overall degradation was 41%, and final TNT soil levels were well above the proposed cleanup level of 30 ppm. Additional studies to evaluate the effectiveness of white rot fungus on explosives-contaminated soil are being sponsored by USAEC.

Bacterial Extracellular Lignin Peroxidase (Crawford, Donald) U.S. Patents 5,200,802, issued 4/06/93 and 5,232,845, issued 8/03/93: This invention provides a secreted lignin peroxidase derived from Streptomyces, and rDNA technology to produce the enzyme. The enzyme has potential applications in wood-pulp processing, detoxification of chloroaromatic environmental pollutants, and assays for such contaminants. It also has potential uses in household stain-removal and fabric-brightener applications. (IRF Case: 4003)

5.10.2.3 Technical Evaluation. This technology has been demonstrated to be capable of decontaminating soils containing a number of hazardous chemicals such as PCB's, trinitrotoluene (TNT), PAH's and chlorinated hydrocarbons. White Rot Fungus with its lignin-degrading or wood-rotting enzyme system has applications for paper and pulp processing. However, no tests have been done to demonstrate the use of fungi for degradation and decontamination of CW or BW agents or their simulants.

5.10.3 Phytoremediation

Phytoremediation is defined as the use of green plants to remove, contain, or render harmless contaminated soil and water. Some phytoremediation methods include Phytoextraction and Rhizofiltration. Both of these methods are used for metals remediation. Phytodegradation, Enhanced Rhizosphere Biodegradation, Organic Pumps, and Phytovolatilization are all phytoremediation methods used for treating organic contaminants. (http://clu-in.com/citguide/phyto.htm)

Phytoextraction, also called phytoaccumulation, refers to the uptake of metal contaminants by plant roots into plant stems and leaves. Certain plants absorb unusually large amounts of metals in comparison to other plants. One or a combination of these plants is selected and planted at a particular site based on the type of metals present and other site conditions. After the plants have been allowed to grow for some time, they are harvested and either incinerated or composted to recycle the metals. This procedure can be repeated as many times as necessary to bring contaminant levels in the soil down to allowable limits. If plants are incinerated, their ash must be disposed of in a hazardous waste landfill, but the volume of ash will only be about 10% of the volume that would be created if the contaminated soil itself were dug up for treatment.

Rhizofiltration (rhizo- means root) has shown promise for dealing with metals contamination in water. Rhizofiltration is similar to phytoextraction, but the plants to be used for cleanup are raised in greenhouses with their roots in water rather than in soil. When the plants have developed a large root system, contaminated water is collected from a waste site and brought to the plants where it is substituted for their water source. The roots take up the water and the contaminants along with it. As the roots become saturated with contaminants, they are harvested and disposed of. In addition to being useful for removing metals from water, rhizofiltration may prove useful for industrial discharge, agricultural runoff, acid mine drainage, and radioactive contamination. For example, sunflowers were used successfully to remove radioactive contaminants from pond water in a test at Chernobyl, Ukraine.

Phytodegradation is a process in which plants break down organic contaminants. Plants use enzymes to degrade and convert ammunition wastes, chlorinated solvents, and herbicides. Enhanced rhizosphere biodegradation is another phytoremediation process used for treating organic contaminants. It takes place in the soil surrounding plant roots. Soil microorganisms found around the roots consume and digest organic substances. Another way in which trees assist in containing contaminants is by acting as organic pumps. Their roots establish a dense root mass that pulls large quantities of water. In doing so, the pulling action of the roots decreases the tendency of pollutants from moving downward toward the water table. Finally, phytovolatilization occurs as growing plants take up organic pollutants along with water. These contaminants pass through the plants before they evaporate.

Enhanced rhizosphere biodegradation takes place in the soil surrounding the plant roots (the rhizosphere) and is a much slower process than phytodegradation. Microorganisms (yeast, fungi, or bacteria) consume and digest organic substances for nutrition and energy. Certain microorganisms can digest organic substances such as fuels or solvents that are hazardous to humans and break them down into harmless products in a process called biodegradation. Natural substances released by the plant roots—sugars, alcohols, and acids—contain organic carbon that provides food for soil microorganisms and the additional nutrients enhance their activity. Biodegradation is also aided by the way plants loosen the soil and transport water to the area.

Trees can act as organic pumps when their roots reach down toward the water table and establish a dense root mass that takes up large quantities of water. Poplar trees, for example, pull out of the ground 30 gallons of water per day, and cottonwoods can absorb up to 350 gallons per day. The pulling action caused by the roots decreases the tendency of surface pollutants to move downward towards ground water and into drinking water. Poplars planted along stream beds in agricultural areas reduce the amount of excess fertilizer and herbicides that get into the streams and ground water. In another similar application, trees planted on top of landfills as organic substitutes for the traditional clay or plastic caps, suck up rainwater that could otherwise seep through the landfill and come out the bottom as contaminated "leachate."

Phytovolatilization occurs as growing trees and other plants take up water and the organic contaminants in it. Some of these contaminants can pass through the plants to the leaves and evaporate, or, into the atmosphere. Poplar trees, for example, volatilize 90% of the TCE they suck up.

Phytoremediation is cost-effective. As a stand-alone process, it can cost 1/10 to 1/3 the cost of conventional remediation technologies. Phytoremediation is a permanent treatment. The contaminant is not only absorbed and removed from a site, only to be moved to another site. The pollutants are destroyed in-situ. Phytoremediation processes in many cases are not a "quick fix". Complete decontamination of a site can take anywhere from weeks to years to achieve a "clean" site, however, plants alone can achieve acceptable levels of decontamination.
(http://www.phytoworks.com/phytofaqs.html)(http://clu-in.com/citguide/phyto.htm)

5.10.3.1 Current Applications. Phytoremediation is most successful at sites with shallow, low-level contamination. Some examples of sites testing phytoremediation are as follows:

Location	Application	Contaminants	Medium	Plant
Ogden, UT	Phytoextraction	Petroleum hydrocarbons	Soil Ground water	Alfalfa, Poplar Juniper, Fescue
Portsmouth, VA	Rhizofiltration Phytodegradation	Petroleum	Soil	Grasses Clover
Milan, TN	Phytodegradation	Explosives wastes	Sediment	Duckweed Parrot feather
Aberdeen, MD	Organic Pumps Phytovolatilization Rhizofiltration	Trichloroethylene Trichloroethane	Ground water	Poplar trees

(http://clu-in.com/citguide/phyto.htm)

Phytoremediation is used for many different purposes including bioremediation of metal contaminated soil and water, and organics contamination - PCBs (polychlorinated biphenyls), TCEs (trichloroethylenes), PAHs (polyaromatic hydrocarbons), pesticide residues, various explosives and other toxic organic pollutants. (http://www.aspp.org/pubaff/phytorem.htm)

5.10.3.1.1 Phytoremediation at Aberdeen Proving Ground. A phytoremediation project is being implemented at Aberdeen Proving Ground (APG) in Maryland in order to clean up a historic bombing range. This site contains groundwater contamination with PCA, tetrachlorine, TCE, and chlorinated solvents due to munitions burning. This site was planted with hybrid poplars and a trench was built to ensure that the trees would be taking up ground water rather than rainwater. The water along with the leaves, stems, and roots of the plants have been monitored. (http://www.clu-in.com/phytomin.htm)

5.10.3.1.2 Phytoremediation Studies at a Naval Air Station in Fort Worth, Texas. The Air Force is conducting a field study to demonstrate the efficacy of using cottonwood trees to remediate TCE-contaminated groundwater. Rows of cottonwoods have been planted perpendicular to groundwater flow in order to intercept the TCE plume. They are looking to see how quickly the tree roots grow down to the water table. Phytoremediation would be cost effective if the roots grow fast. Thus far, the trees have grown very quickly and this method shows promise. The Air Force has plans to analyze concentration changes of TCE, vinyl chloride, and haloacetic acids. (http://www.clu-in.com/phytomin.htm)

5.10.3.1.3 Phytoremediation Studies at the University of Iowa. Phytoremediation was studied at the University of Iowa using twenty different contaminants. Some of these contaminants included atrazine, alachlor, TCE, BTEX, chlorobenzene, benzo(a)pyrene, BEHP, chlordane, nitrobenzene, aniline, TNT, RDX, and 1,4-dioxane. These contaminants were examined for uptake, volatilization, and soil mineralization. (http://www.clu-in.com/phytomin.htm)

5.10.3.2. Evaluation Results. Innocuous products have been found using 14C-compounds for atrazine and TCE in poplars and vegetables. Tests have shown that soil containing an atrazine concentration of 138 ppm was decreased to 20 ppm after two growing seasons. Cleavage products of atrazine were found within 80 days from the beginning of the experiment. (http://www.clu-in.com/phytomin.htm)

Scientists have investigated using phytoremeditaion techniques to reduce radionuclide contamination in ground and surface waters. Rhizofiltration was tested in the summer of 1995 at two locations; Ashtabula, Ohio, a DOE site contaminated with 100-400 ppb uranium in ground and surface water and in a small pond within 1 km of the Chernobyl nuclear power plant in the Ukraine. The field results demonstrated that rhizofiltration is a practical way to treat radionuclide-contaminated water.

5.10.3.3. Technical Assesment. Phytoremediation can be used to clean up metals, pesticides, solvents, explosives, crude oil, polyaromatic hydrocarbons, and landfill leachates. Phytoremediation is used in combination with other cleanup approaches as a "finishing" step. Although phytoremediation is significantly slower than mechanical methods, and is limited to the depth that the roots can reach, it can clean out the last remains of contaminants trapped in the soil that mechanical treatment techniques sometimes leave behind.

Generally, the use of phytoremediation is limited to sites with lower contaminant concentrations and contamination in shallow soils, streams, and ground water. However, researchers are finding that the use of trees (rather than smaller plants) allows them to treat deeper contamination because tree roots penetrate more deeply into the ground. Contaminated ground water very deep underground may be treated by pumping the water out of the ground and using it to irrigate plantations of trees.

Further research is needed to study the effects on the food chain that could occur if insects and small rodents eat the plants that are collecting metals and are then eaten by larger mammals. Also, scientists still need to establish whether contaminants can collect in the leaves and wood of trees used for phytoremediation and be released when the leaves fall in the autumn or when firewood or mulch from the trees is used.

5.11 Decontamination of Biological Agents

Biological agents are living microorganisms that have the capacity to cause debilitating disease or death in man, animals, or plants. Toxin agents are virulently poisonous substances, often proteins, with specific biological properties including immunogenicity produced by living organisms. Different types of biological agents can be classified as either viruses, Rickettsiae, Bacteria, or Fungi. Viruses are one of the simplest forms of life. In order to reproduce they must inject their genetic material (DNA or RNA) into the host. Viral diseases which may be used as biological warfare agents are Venezuelan Equinine Encephalitis, Crimean-Congo Hemorrhagic fever, Argentine Hemorrhagic fever, Rift Valley Fever, and Yellow Fever. Rickettsiae are obligate parasites that live within the cells of their host causing Q-Fever, and Rocky Mountain Spotted Fever. Bacterial diseases that could be used for biological warfare are anthrax, cholera, plague, and tularemia. Fungi are used to produce toxins such as the aflatoxins and trichothecene toxins.

Decontamination of biological agents requires that the agent be exposed to conditions that interrupt the natural biochemical processes needed to sustain the life of the organism. Anything which destroys proteins, DNA, RNA, cell walls, or disrupts the transport systems within the pathogenic organisms cell will kill the organism. For example, heating any living organism above a specific temperature will cause the proteins and nucleic acids in the cell to coagulate, thereby destroying their capability to carry out their biological function. Heat combined with moisture (moist heat) is used to destroy biological agents. The presence of moisture assists in the coagulation of proteins and the rapid transfer of heat throughout the materials being heated. Moist heat under pressure in a piece of equipment called an autoclave, is capable of not only destroying vegetative cells of pathogenic bacteria but also certain heat resistant spores of bacteria. This is because in the autoclave the water/steam temperature can be raised above the normal boiling point of water.

Oxidation of the biological agent is another approach to decontamination. Chemical oxidants such as ozone, hydrogen peroxide, peracetic acid, hypochlorite, and chlorine dioxide are all used to destroy living biological agents. Alkylating agents such as ethylene oxide, formaldehyde, glutaraldehyde and beta-propiolactone interfere with the normal metabolism of protein and reproductive processes resulting in cell death. A currently acceptable method for gaseous decontamination of laboratories bio-safety cabinets and high efficiency particulate air (HEPA) filters involves the use of paraformaldahyde crystals sublimed by heat in the presence of high humidity. However, human contact with the formaldahyde must be prevented because of the highly irritating, toxic, and possibly carcinogenic properties of the gas formed.

Another approach to decontamination of biological warfare agents is the use of high energy gamma rays. Irradiation with gamma rays causes the formation of highly reactive free radicals that can disrupt strands of nucleic acid, inactivate proteins, and destroy the cell walls of biological agents.

5.11.1 Current Applications

Ethylene oxide is used in gaseous form to sterilize. The advantages of EO are that materials can be treated at low temperatures, and EO is good at penetrating into porous materials. The disadvantages of EO are that it is toxic and highly flammable and can cause explosions if mixed with air. To minimize risks EO can be mixed with inert gases such as nitrogen or carbon dioxide, effectively diluting the EO vapors. Glutaraldehyde is a germicidal that destroys most vegetative microorganisms within a few minutes. It is most germicidal in the alkaline pH range and so a 0.3% sodium bicarbonate solution is added to a glutaraldehyde solution just before it is to be used. An alkaline pH results and the solution is then said to be activated. Moist heat is used in conjunction with pressure in autoclaves to sterilize equipment for surgical procedures ranging from dental work to major surgery.

5.11.2 Evaluation Results

The decontamination of biologically contaminated surface with decontaminating apparatus was conducted to evaluate the efficiency of the M13 apparatus for biological decontamination (CBIAC AD-B089-043). Three decontaminant solutions were used:

- Acidified Sodium Hypochlorite (ASH) composed of 1 gallon tap water, 15.2 ml distilled white vinegar (5% acid strength), and 15.2 ml household bleach (5.25% by weight sodium hypochlorite)
- Diluted bleach composed of 1 gallon tap water 15.2 ml household bleach (5.25% by weight sodium hypochlorite)
- Water

The test organisms used were bacillus subtilis var niger spores, commonly known as Bg. Test strips 1 inch x 3 inch x 1/16 inch coated with polyurethane-painted steel plates were attached to the wheel wells of an M113 armored personnel carrier. Single test strips were attached to the first 4 wheels starting from the back of the vehicle. The test strips were contaminated solely by aerosol fallout generated by a small cylindrical chamber (14 inches in height and 11 inches in diameter) by producing 18 squeezes (50 ml each) of a rubber bulb connected to a Devilbisss #40 glass nebulizer containing aqueous Bg suspension. The decontamination procedure consisted of one spray on all strips followed by a back and forth stroke with the brush. The whole sequence took about 30 seconds for all three strips. The runoff from the wheel wells was collected and analyzed for spore activity, also the operator wore an M9A1 protective mask fitted with a man-mask sampler to assess the degree of secondary aerosol hazard generated. Results are shown in Tables 5.11.2-1, 5.11.2-2, and 5.11-3.

Table 5.11.2-1. Decontamination of M113 Test Strips – Residual Agent on Strips

Decontamination Solution	Strip #	Total Spores on Strip After Spray	Average Percent Reduction
Water	1	$8.9x10^4$	96.8
	2	$6.2x10^4$	
	3	$3.6x10^4$	
Bleach	1	$4.5x10^4$	98.0
	2	$4.0x10^4$	
	3	$4.0x10^4$	
ASH	1	$1.1x10^4$	99.6
	2	$5.3x10^3$	
	3	$5.6x10^3$	

Table 5.11.2-2. Decontamination of M113 Test Strips – Agent in Diluted Bleach Runoff

Contact Time (min.)	Total Spore Count/10 ml	Survival (%)
0	41430	100
1.25	9800	24
4.5	116	0.28
27.0	6	0.014

Table 5.11.2-3. Decontamination of M113 Test Strips – Secondary Aerosol Data

Spray Fluid	Spore Recovery	Sampling Period (min.)	Spores Recovered/min
Water	443	1.5	315
Bleach	116	0.5	232
Ash	37	0.5	74

From the data presented, the following conclusions were reached:

- Ash performance is superior to diluted bleach and water
- The presence of dirt, mud, and foreign material will greatly reduce the germicidal power of ASH
- The M13 decontamination apparatus can be used for biological decontamination but is limited to small areas and easily reachable locations.

During the period 1945 to 1972, over 550 compounds were tested for vapor phase bactericidal activity. The samples were evaluated against the following criteria to determine suitability for follow-on testing.

- Effective against all microorganisms
- Fast acting even at low concentrations
- Effective over a wide range of temperatures and humidity
- Good penetrating power
- Not too irritating and/or toxic: non-carcinogenic
- Not too damaging to furnishings
- Not too flammable or explosive
- Easy to disseminate, contain, and remove, leaves no residue.
- Stable in storage
- Inexpensive.

Twenty-one from the over 550 compounds were selected for testing using a new more rigorous test.

Under this study, the 21 compounds were tested using more rigorous test conditions (CBIAC AD-A084392). Bg spores were used as the biological agent simulant. Patches of Chemical Corps #5 paper, which is a special asbestos impregnated paper with a cloth webbing backing, were contaminated with a 0.1 ml Bg suspension. The contaminated paper was then air dried for 3 hours and stored under 80% relative humidity. The contaminated patches were hung in a closed bottle containing the test material. The decontaminant was placed into the bottle, the bottle sealed with a rubber stopper which also held the contaminated paper strips. The paper was exposed to the test vapors for 24 hours after which time the paper was removed and air-dried for 1 hour. The dried contaminated strips were then placed into 100 ml of sterile water and shaken for 5 minutes. Samples of the water were taken diluted and placed onto plates containing Difco Tryptose Agar. The plates were then incubated for 48 hours at 37°C. The most favorable results are shown in Figure 5.11.2-4.

Table 5.11.2-4. Test Results

Compound	Conc. mg/L	Relative Humidity	Temperature, °C	Bg Spore Kill	Comment or Special Condition
Glyoxal (30% aqueous solution)	12	100	23	100	
	9	100	Room	99.999	
Propargyl alcohol	22	Room	23	98.86	
	24	Room	Room	99.85	36% kill in 4 hrs.
Formaldehyde (37% aqueous solution)	10	100	23	100	
	10	100	Room	100	

Several additional compounds that had not previously been tested were tested for sporicidal activity. The most favorable results are shown in Figure 5.11.2-5.

Table 5.11.2-5. Results of Additional Compounds Tested

Compound	Conc. mg/L	Relative Humidity	Bg Spore Kill
Formic acid	36	90 – 100	100
Hypochlorous acid (2.5% aqueous solution)	0.7	100	100
Nitric acid (70% aqueous solution)	23	100	100
Nitrogen dioxide (gas)	0.5	90 – 100	100
Nitrous acid (2.5% aqueous solution)	0.7	100	100
Trifluoroacetic acid	9	90 – 100	100
Trifluoroacetic acid anhydride	20	Room	100

Autoclaving was used in the U.S. demilitarization operations at Dugway Proving Ground to inactivate botulinum toxin residue on munition components. These were autoclaved for three hours at 121°C and 15 PSI. (L.L. Salomon and J.K. McBride. "Disposal of Biological Agents and Munitions", Dugway, Utah: Desert Test Center, 1968.)

Out of a large number of candidate compounds six met the required activity requirements when tested by the tube dilution method against *Bacillus subtilis* spores (Bg) and *Serratia marcescens* (SM). Formaldehyde vapors and hypochlorite compounds were found to be most promising in decontaminating aircraft interiors. It was also determined that hypochlorites were superior to decontaminating large spills of biological agents (CBIAC AD-892397).

A detailed theoretical and experimental investigation was conducted to prepare a design concept for a Beta-Propiolactone (BPL) Vapor Generator to be used for biological decontamination of buildings. Based on this study a prototype generator was fabricated and tested for performance. The generator vaporizes 0.017 gallon BPL per minute in 420 cfm of 25°C air. The portable generator was powered by a 115 volt A.C. amp. electrical circuit and all components are corrosion resistant to BPL. The major components were a 1 gallon BPL reservoir, pump, fogging nozzles, heating element, mixing chamber and a filter to remove entrained BPL droplets. Complete operation and maintenance instructions were formulated for the generator (CBIAC AD-825609).

Modified fire fighting foam was evaluated to decontaminate biological simulants, a corona discharge system was built and evaluated for decontamination of biological simulants, and an electrostatic fence was constructed and tested for protection of small enclosures from biological simulants. (CBIAC AD-B079030)

This report recommends using solutions of chlorine bleach (hypochlorites) with and without pH control as field-expedient biological decontaminants. These solutions are recommended because of their ready availability, low cost, easy use, familiarity to everyday experience, speedy action and potency against all types of microorganisms including Bacillus anthracis (anthrax) spores which are considered the most persistent and most difficult to kill of the known, potential, biological threat agents. (CBDCOM AD- B091 354)

Practical trials were conducted on an operating destroyer to determine if BW contamination could be effectively destroyed. Two vapor disinfectants were used, formaldehyde vapor and carboxide (ethylene oxide and carbon dioxide) to destroy agents after passing through a simulated BW aerosol. Formaldehyde vapor was determined to give the best results for decontamination. (CBIAC AD- 264205)

The M17 Sanator was used to decontaminate an M3 Bradley and an M54 truck that were contaminated with *Bacillus subtilis* var. niger (Bg). The vehicle was decontaminated with hot and cold water and with and without detergent. All conditions removed >95% of the contamination from the vehicle surfaces, however, more tests were called for since measurable amounts of organisms were left on the vehicles after decontamination (CBIAC AD- B173912).

The effects of washing trucks contaminated traveling in a convoy over concrete and dirt roadways with BW simulants was studied. The extent of contamination ranged from 0 to 8,500 organisms/in^2 on concrete roads and 0 to 17,000 organisms/in^2 on dirt roads. Washing for 30 minutes with a high pressure water stream or the use of a steam cleaner gave the same extent of removal on the first wash, about 85 to 95%. A second washing with the steam cleaner gave further reduction which was far greater than a second washing with water alone (DTIC AD- 262870).

5.11.3 Technical Assessment

Decontamination techniques for biological warfare agents can use many of the same approaches used for chemical decontamination. In the case of living organisms such as bacteria, environmental conditions such as temperature, pH, and chemical corrosivity (using bleaches) can be adjusted to effectively destroy all organisms. In the case of organisms that form spores when the environmental conditions become too harsh for life, more vigorous methods of decontamination need to be done.

Because of the corrosivity and reactivity of decontaminants new approaches are being investigated. New sorbent materials are being investigated that preferentially bind and immobilize the organism. Once immobilized the organism loses its ability to infect the host making it non-toxic. Work at the U.S. Army ECBC has produced materials composed of dendritic polymers coated with highly selective antibodies. The antibodies preferentially bind the selected BW agent making it inert. The dendritic polymer substrate aids in making the system more reactive towards BW agents by forcing the antibodies to align parallel to one another on the surface. Another approach to sorbent materials for BW utilizes antibodies attached or trapped in a sol gel or aerogel matrix. Sol gels and aerogels are three-dimensional structures of silicon dioxide (glass) which can be readily prepared from simple chemicals. Once the antibody it immobilized into the sol gel or aerogel particle it can bind to any BW agent which the particle comes in contact with effectively neutralizing the biological activity of the agent. Immobilization of the antibody onto the sol gel/aerogel matrix has been called making the sand smart, therefore this technology has been named "smart sand".

6.0 CB Decontamination Equipment.

This section provides a detailed listing and description of all military and commercial CB decontamination equipment identified through the Literature Search and Market Survey efforts.

6.1 Aboukir Engineering Industries Inc - EGYPT.

6.1.1 Multipurpose Decontamination Vehicle.

The Multipurpose Decontamination Vehicle, shown in Figure 6.1.1, is used to carry various types of decontamination equipment and materials for the purpose of decontaminating personnel, equipment, and large areas (i.e. terrain). The vehicle was developed and manufactured in Egypt by Aboukir Engineering Industries and is employed by the Egyptian armed forces. Utilizing the equipment carried on the vehicle, it is possible to decontaminate 5 to 7 large vehicles (i.e. tanks), between 10 and 15 medium-sized vehicles, and 20 to 30 small vehicles in one hour. A spray bar is used to decontaminate a strip of terrain 3 meters wide while the vehicle travels at a speed of 6 km/hour.[1] The Multipurpose Decontamination Vehicle is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

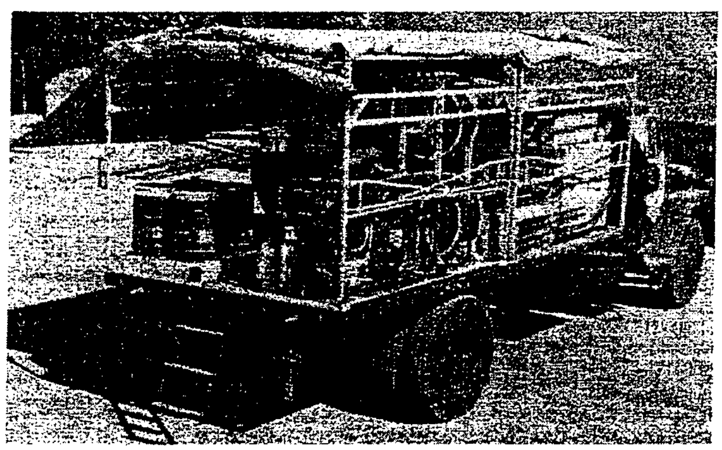


Figure 6.1.1. The Multipurpose Decontamination Vehicle, manufactured by Aboukir Engineering Industries Inc. Egypt, is employed by the Egyptian armed forces. Photo reproduced with permission from Jane's Information Group.

6.2 ACD Salvage Techniek – NETHERLANDS.

6.2.1 ACD Hazmat Shower.

The ACD Hazmat Shower is a portable decontamination shower designed to decontaminate skin and personal equipment. The ACD Hazmat-Shower is commercially available in the Netherlands and is manufactured by ACD Salvage Techniek. The shower employs mechanical (primary) and shower chemical (secondary) technologies. The Hazmat Shower uses high-pressure sprays and is constructed from stainless steel. The shower unit can be assembled in 15 seconds and is usually placed within a basin to collect contaminated water. The shower is equipped with nine nozzles to cover the contaminated individual. A chemical inducer can be added to the shower so that a decontaminant can be introduced into the water stream for further decontamination. The water flow of the system ranges from 25 to 200 liters per minute with a pressure of 5 bar. The Hazmat Shower, shown in Figure 6.2.1, weighs 23 kg (50 lbs) and is 1140 mm long, 205 mm wide, and 390 mm high. The unit is foldable and can be easily transported. The ACD Hazmat-Shower is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.2.1. The ACD Hazmat Shower is a portable decontamination shower designed to decontaminate skin and personal equipment.

6.2.2 <u>Deko Circle</u>.

The Deko Circle is a Hazmat Shower hoop designed to decontaminate skin and personal equipment. The shower hoop, manufactured in the Netherlands by ACD Salvage Techniek, disseminates a high-pressure spray of water or a substituted decontaminant. Depending on the decontaminant chosen, the Deko Circle may employ chemical technology or mechanical technology. The shower is made from stainless steel and is octagon shaped with an extendable handle. The hoop is passed over a contaminated individual as water is sprayed out of eight nozzles, one nozzle on each branch of the octagon. The hoop sprays 30 liters of water (or a substituted decontaminant) per minute at a pressure of 4 bar. The hoop has a diameter of 47 inches and weighs 8.4 pounds. The Deko Circle is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.2.2 The Deko Circle disseminates a high-pressure spray of water or a substituted decontaminant.

6.3 ACMAT (Ateliers de Construction Mecanique de l'Atlantique) - FRANCE.

6.3.1 UMTH 1000 Vehicle-Mounted Decontamination System.

The UMTH 1000 is a vehicle mounted decontamination system used to decontaminate exterior equipment that has been exposed to chemical agents. The system, manufactured in France by ACMAT (Ateliers de Construction Mecanique de l'Atlantique), is used by the French Army. The UMTH 1000 employs mechanical technology and disseminates hot water and steam at high-pressures. The system is comprised of four main components: a hydraulic transformation mobile unit UMTH 1000 (a high-pressure hot water and steam generator), a motor pump with a 3,000 liter water tank, an equipment platform, and fixed hydraulic equipment.

The vehicle is equipped with chemical detection equipment and protective clothing for the crew. The entire system is 6.91 L x 2.31 W x 2.6 H meters and weighs 11,800 kg. The vehicle's maximum speed is 90 km/hour and has a range of 1,600 km.[1] The UMTH 1000 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

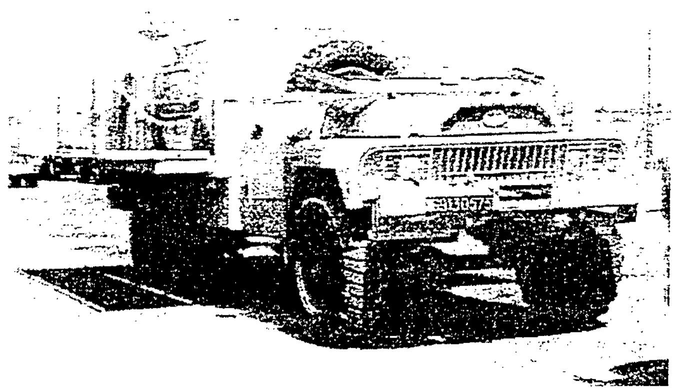


Figure 6.3.1. The UMTH 1000 Vehicle-Mounted Decontamination System Manufactured by Ateliers de Construction Mecanique de l'Atlantique, France. Photo reproduced with permission from Jane's Information Group.

6.4 Aerochem - GERMANY.

6.4.1 C-Selfaid-Kit.

The C-Selfaid-Kit is a compact kit that enables the detection and decontamination of liquid chemical agents, as well as first therapy against nerve agent poisoning. The kit is commercially available and is manufactured in Germany by Aerochem. The kit enables an individual to conduct skin and personal equipment decontamination in the event of exposure to chemical warfare agents. The kit employs sorbent technology and comes equipped with a 1 x 60 g canister of decontaminating powder (described in decontaminant section). The kit is equipped with several decontamination aids (i.e. 10 chemical pads, 60 x 60 mm fiber fleece; 10 antistatic towels, 60 x 60 mm; 2 x 2 ear plugs; 1 x 25 g special soft soap; and 5 medical adhesive tapes). The kit is also equipped with a booklet of detection paper for liquid chemical agents, and atropine to help prolong survival of a victim. The C-Selfaid-Kit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.4.2 Decontamination Towel.

The Decontamination Towel is used for the decontamination of skin and personal equipment, sensitive equipment, and interior equipment. The towel is commercially available and employs chemical technology (oxidation) to remove chemical agents from surfaces. Chemical agents are first dabbed-off a surface with one side of the towel and then wiped off completely with the clean side of the towel. It contains morpholine, chloramine, alcohol, and water. The towel is 250 x 320 mm and comes folded in a sealed plastic packet.[1] The Decontamination Towel is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	

6.5 Aero Tec Laboratories, Inc – UNITED STATES.

6.5.1 Speedi-Berm.

Speedi-Berm, shown in Figure 6.5.1, is a commercially available, stand-alone, spill containment system. It was designed and manufactured by Aero Tec Laboratories Inc. Speedi-Berm is used by the U.S. DoD decontamination teams, hospitals, and chemical plants. Speedi-Berm is used to contain oil, fuel, hydraulic fluids, solvents, wastes, anti-freeze, etc. Moreover, it protects against spills and the overflow of decontaminant solvents and washwater. Speedi-Berm employs a spring-loaded aluminum buttress that deploys automatically to support the side walls. Speedi-Berm is available in over 20 different sizes and can accommodate anything from a pile of contaminated soil to tractor-trailers and aircraft. Speedi-Berm is made from high-tenacity rubberized fabrics to ensure high chemical resistances. Speedi-Berm's NSN number is 4235014194801 and ranges in price from $600 to $10.000. Speedi-Berm may be used to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

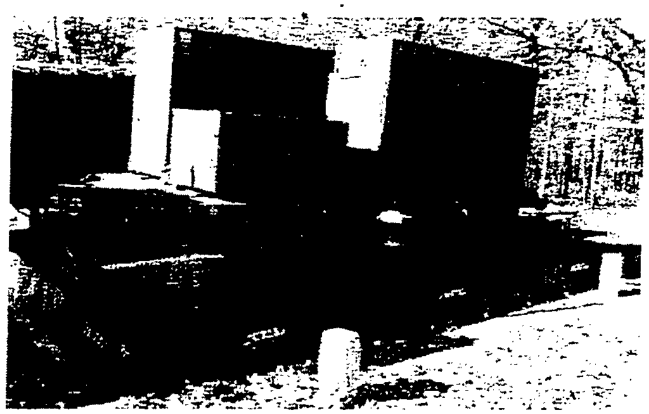


Figure 6.5.1. Speedi-Berm, manufactured by Aero Tec Laboratories, U.S., is a commercially available, stand-alone, spill containment system. Photo Courtesy of Aero Tec Laboratories.

6.5.2 Port-A-Berm.

The Port-A-Berm is a commercially available, stand-alone, secondary containment system. Designed and manufactured in the U.S., the Port-A-Berm is employed by the U.S. DoD, decontamination teams, hospitals, and chemical plants. The Port-A-Berm is used to catch drips, spills, leaks, and overflow of decontaminant solvents, washwater, and other chemicals. The Port-A-Berm inflates to a firm apparatus in ten minutes using a low pressure fan, blower, foot pump, or vehicle exhaust. One end-tube may be deflated to allow large vehicles drive-on access. The Port-A-Berm is available in over 20 different sizes and can accommodate anything from a pile of contaminated soil to tractor-trailers and aircraft. The Port-A-Berm is made from high-tenacity rubberized fabrics to ensure high chemical resistances. The Port-A-Berm sells from $600 to $10,000. Port-A-Berm is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

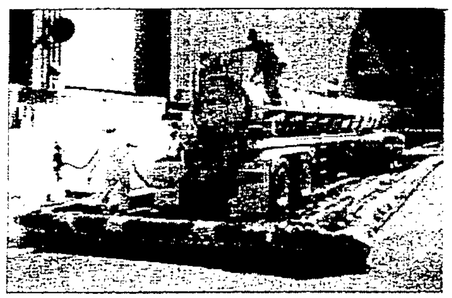


Figure 6.5.2. Port-A-Berm, manufactured by Aero Tec Laboratories, U.S., is a commercially available, durable, secondary containment system. Photo Courtesy of Aero Tec Laboratories.

6.6 AEROSTAR SA - Romania.

6.6.1 <u>ADTT-1 Jet Decontamination Truck-Mounted Installation</u>.

The ADTT-1 is a truck-mounted decontamination system that uses jet engine exhaust to decontaminate exterior equipment (i.e. vehicles). The ADTT-1, manufactured in Romania by Aerostar, employs low-temperature thermal technology. However, depending on which decontaminating solutions are utilized, mechanical and chemical technologies may also be employed. The jet engine used with the ADTT-1 is a turntable-mounted RD 45 FA (MO5) turbine that operates between 8,000 and 11,000 rpm. The jet engine is capable of producing a gas jet up to 9 meters long into which decontaminating agents are added. The gas jet is directed and controlled by an operator seated in a cab to the right of the jet engine. The operator communicates with the vehicle driver via an intercom system. The ADTT-1 may be used for a variety of different applications including clearing snow from runways, aircraft de-icing, and dousing flames.[1] The ADTT-1 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.7 Alfred Karcher GmbH & Co - GERMANY.

6.7.1 Karcher Decojet Decontamination System.

The Decojet Decontamination system is used to decontaminate skin and personal equipment. The Decojet, shown in Figure 6.7.1, employs both mechanical and chemical technologies to decontaminate items by disseminating both water and mixtures of decontaminant solutions at high-pressures onto contaminated surfaces. The system is equipped with a 435 liter water tank with a run-back pipe that preheats the water in the tank. An additional 200 liter water tank is available along with an injector system for mixing and applying decontamination solutions. The system also contains a two-stage personnel shower with an injection system in order to allow the addition of deconaminants to the water jets. The Decojet is used as a quick reaction first aid decontamination system close to the front line or as a company level self-decontamination measure. The system weighs 1.055kg and is 1.653 m long, 1.41 m wide, and 1.24 m high.[1] The Decojet is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.7.1. The Karcher Decojet System is used to decontaminate skin and personnel equipment. Photo reproduced with permission from Jane's Information Group.

6.7.2 Karcher DECOCONTAIN 1500 Decontamination System.

The DECOCONTAIN 1500 is a compact decontamination system designed to decontaminate skin and personal equipment, exterior equipment, and large areas against both biological and chemical agents. The system, shown in Figure 6.7.2, employs chemical (primary) and mechanical (secondary) technologies. The DECOCONTAIN 1500 disperses microemulsions, water, and other decontaminants at high pressures. The system is constructed as a main component for NBC-defense troops and is the basis for the setting-up of a decontamination site.

Material decontamination is conducted in 3 steps; pre-wash, main treatment, and post-treatment. A number of separate decontamination modules (i.e., Karcher MPS 3200, C8-DADS, and MPDS) are housed in the DECOCONTAIN 1500 in order to perform decontamination. During pre-treatment, tanks, vehicles, and other equipment are cleansed of heavy soiling which contains contamination using the high pressure (55 bar) and cold water of the MPS 3200. During main treatment, the C8 DADS module is used. Decontamination is accomplished using the Karcher detoxification emulsion TDE 202.

Personnel decontamination is achieved using a two-step, pulsating shower procedure. Detoxification and disinfection of clothing and equipment is carried out using steam. Terrain decontamination can be achieved using an aqueous detoxification solution. Terrain decontamination may require employing additional technologies, such as oxidation, aqueous strong bases, semi-aqueous/non-aqueous, and solvent.

The DECOCONTAIN 1500 is 5.0 m long, 2.2 m wide, and 2.2 m high. It weighs 4,900 kg and can operate in a temperature range from –20 to +50 °C. The system is equipped with a 1,500 liter tank and can decontaminate 6 to 8 tanks or 12 to 16 vehicles in 1 hour, 15 to 20 sets of clothing in 1 hour, and 10,000 m^2 of terrain in 1 hour.[1] The DECOCONTAIN 1500 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

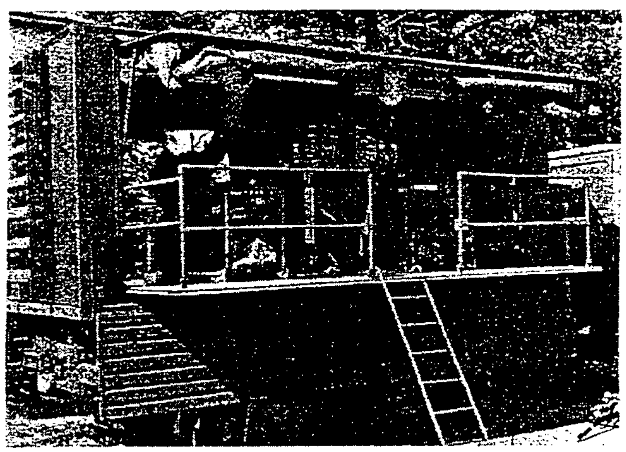


Figure 6.7.2. The Karcher DECOCONTAIN 1500 is a compact decontamination system designed to decontaminate skin and personal equipment, exterior equipment, and large areas. Photo reproduced with permission from Jane's Information Group.

6.7.3 Karcher DECOCONTAIN 3000 Decontamination System.

The DECOCONTAIN 3000 is similar to the DECOCONTAIN 1500 and is also designed to decontaminate skin and personal equipment, exterior equipment, and large areas against both biological and chemical agents. The DECOCONTAIN 3000 employs chemical (primary) and mechanical (secondary) technologies and disperses microemulsions, water, and other decontaminants at high pressures. It was designed for deployment at battalion level or higher and forms the technical basis for the setting-up a decontamination site.

Material decontamination is conducted in 3 steps: pre-wash, main treatment, and post-treatment. A number of separate decontamination modules (i.e. Karcher MPS 3200, C8-DADS, and MPDS) are housed in the Decocontain 3000 in order to carry out thorough decontamination. During pre-treatment, tanks, vehicles, and other equipment are cleansed of heavy soiling which contains contamination using high pressure (55 bar) cold water. During main treatment, the C8 DADS module is used. The MPDS module is used in the post-treatment to remove the decontamination with steam heated to 140 °C. The detoxification of chemical agents is accomplished using the Karcher detoxification emulsion TDE 202.

Personnel decontamination is achieved using a two-step, pulsating shower procedure. Detoxification and disinfection of clothing and equipment is carried out using hot steam. Moreover, terrain decontamination can be achieved using an aqueous detoxification solution. Terrain decontamination may require employing additional technologies, such as oxidation, aqueous strong bases, semi-aqueous/non-aqueous, and solvent.

The DECOCONTAIN 3000, shown in Figure 6.7.3, is 6.058 m long, 2.438 m wide, and 2.438 m high. It weighs 11,500 kg and can operate in a temperature range from −20 to +50 °C. The system is equipped with a 3,000 liter tank and can decontaminate 6 to 8 tanks or 12 to 16 vehicles in 1 hour, 20 to 30 sets of clothing in 1 hour, 120 persons in one hour, and 10,000 m^2 of terrain in 1 hour.[1] The DECOCONTAIN 3000 supports the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

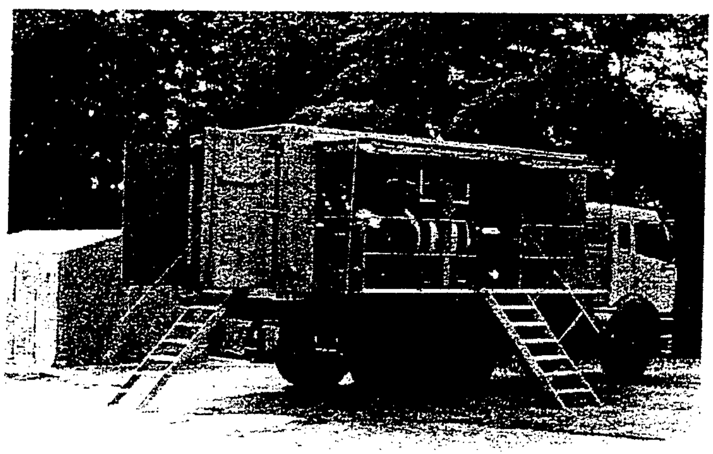


Figure 6.7.3. The Karcher DECOCONTAIN 3000 is equipped with a 3,000 liter tank and can decontaminate 6 to 8 tanks or 12 to 16 vehicles in 1 hour, 20 to 30 sets of clothing in 1 hour, 120 persons in one hour, and 10,000 m^2 of terrain in 1 hour.

6.7.4 <u>Karcher Decontamination Trailer</u>.

The Decontamination Trailer is a mobile decontamination system. The Decontamination Trailer, used throughout Europe, employs chemical (primary) and mechanical (secondary) technologies. The system uses a high-pressure spray of water in the pre-wash and a high-pressure decontamination emulsion for main treatment. The trailer consists of two subsystems: the trailer and a removable platform. The trailer is designed for the decontamination of both equipment exterior and skin and personal equipment, while the platform is used primarily for the decontamination of equipment exteriors.

The trailer-mounted subsystem consists of three modules; a cold water high-pressure unit for the prewash, a decontamination emulsion generator for the main treatment, and a steam generator for the post-treatment with hot steam. The trailer is also equipped with a shower unit and a tent for the decontamination of skin and personal equipment.

The platform subsystem comprises of two modules: a decontamination emulsion generator for the main treatment and a steam generator. The steam generator sprays cold water for the prewash and steam for post-treatment. Water is stored in a 1,000 liter tank to ensure immediate start-up. The entire trailer subsystem and platform subsystem weighs 5,000 kg and is 6.5 m long, 2.3 m wide, and 2.6 m high.[1] The Decontamination Trailer supports the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.7.5 Karcher C8-DADS Direct Application Decontamination System.

The C8-DADS is designed for the decontamination of exterior equipment and large areas. The system is in service with Australia, Austria, Egypt, France, Germany, Taiwan, Thailand, and NATO armed forces. The C8-DADS employs chemical (primary) and mechanical (secondary) technologies. The high-pressure spray system is driven by an air-cooled 4-stroke diesel engine that drives a 75 bar water pump, a solvent pump for liquid agents, and two hydraulic pumps. Optimum detoxification is accomplished using the Munster (C8) emulsion after cleaning the surface with high-pressure cold water. Tanks and large vehicles with CARC require approximately 150 liters of emulsion, while 300 liters are required if the vehicle is not treated. The C8-DADS, shown in Figure 6.7.5, uses an aqueous C8 solution to decontaminate chemical and biological warfare agents. To decontaminate terrain, vehicle mounted spray nozzles disperse the decontamination solutions. The basic module can mix up to 254 kg of C8 with water (volume of 1,300 liters) that can be increased with additional pumping systems. The C8-DADS weighs 320 kg and is 0.96 m long and 0.85 m high. The system may be carried on a truck with the components mounted in a tubular steel frame.[1] The C8-DADS supports the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

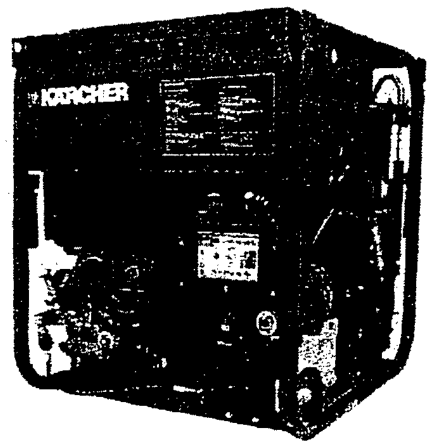


Figure 6.7.5. The Karcher C8-DADS may be carried on a truck for the decontamination of exterior equipment and large areas.

6.7.6 Karcher Portable Lightweight Decontamination System DS 10.

The DS 10, shown in Figure 6.7.6, is a portable lightweight decontamination system designed for the CB decontamination of personal equipment, exterior equipment (i.e. vehicles, aircraft, protective suits). The system is in service with Austria, Belgium, Germany, Norway, Sweden, and some countries in the Middle East. The DS 10, depending on the decontaminant used, may employ either mechanical or chemical technologies. This high-pressure system is equipped with a mixing device to generate different solutions or emulsions, thus allowing it to decontaminate a wide variety of items. The DS 10 consists of a 10-liter pressure tank, a mixing device, and an air pump to pressurize the system. A pressure relief valve opens if the maximum operating pressure (6 bar) is exceeded. The manually operated device can treat an area of at least 50 m^2 and has an operating time of more than 5 minutes per filling. The system weights 9.5 kg, 704 mm in height, and 210 mm in diameter.* The system has a maximum operating temperature of 60 °C.[1] The Karcher DS 10 supports the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

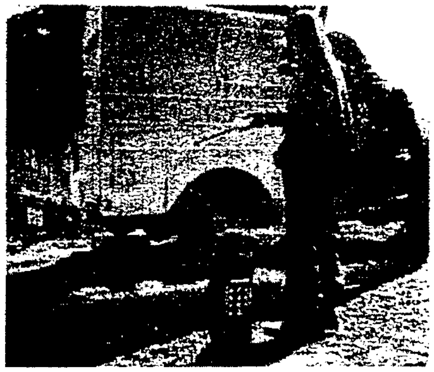


Figure 6.7.6. The DS 10 high-pressure system is equipped with a mixing device to generate different solutions or emulsions, thus allowing it to decontaminate a wide variety of items.

6.7.7 Karcher Decont Jet 21.

The Decont Jet 21, shown in Figure 6.7.7, is designed to decontaminate exterior equipment. The system employs mechanical technology and disseminates water at high-pressures. The Decont Jet 21 is comprised of two sub-systems, a high-pressure water spray stem and a gas turbine for decontamination with hot gas. Both sub-systems are mounted on a semi-trailer mobile platform. The frame is held by a hydraulic crane and is equipped with high-pressure rotating nozzles and guidance arrangements for the hot gases. The system's telescopic design allows the decontamination of any size vehicle and large areas of terrain. The system is equipped with a water tank capacity of 6,000 liters, a fuel consumption rate of 870 liters/hour, and an operating temperature range from -40°C to +50°C. The Decont Jet 21 can decontaminate 6 tanks or 10 vehicles per hour. The system weighs 27,000 kg and is 12.4 m long, 2.5 m wide, and 3.25 m high. The Decont Jet 21 supports the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

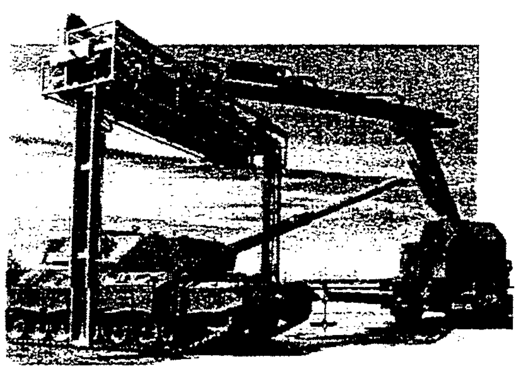


Figure 6.7.7. The Karcher Decont Jet 21's telescopic design allows the decontamination of any size vehicle and large areas of terrain.

6.7.8 Karcher HDS 1200 EK High Pressure Steam Jet Cleaner Unit.

The HDS 1200 EK is a high-pressure steam jet cleaner unit is used for a variety of decontamination tasks. This system, in service with the German armed forces, employs mechanical technology and disseminates high-pressure cold or hot water, steam, or dry steam to decon contaminated materials. The system utilizes a high-pressure pump (up to 50 bar) capable of raising water up to 5 m from streams and rivers. All system components are mounted on skids with fold-down wheels. The entire system weighs 280 kg and is 1.45 m by 0.75 m by 1.11 m high.[1] The HDS 1200 EK supports the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

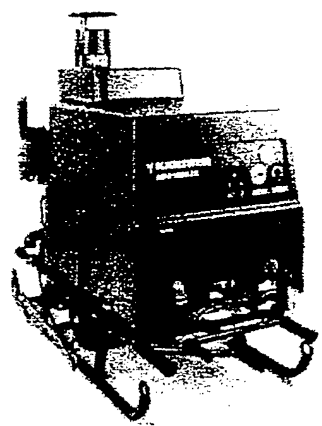


Figure 6.7.8. The Karcher HDS 1200 EK employs water technology and disseminates high-pressure cold or hot water, steam, or dry steam for decontamination of contaminated materials. Photo reproduced with permission from Jane's Information Group.

6.7.9 Karcher SCS 1200 DE Lightweight Decontamination System.

The SCS 1200 DE is a lightweight decontamination system designed to decontaminate skin and personal equipment, and exterior equipment (i.e. tracked and wheeled vehicles, aircraft). The system employs mechanical technology and can disseminate pressurized cold water, hot water, and hot steam with a maximum steam output temperature of 130°C. The system has an output rate of 450 to 1,200 liters/hour and a pressure range of 60 to 130 bar and is powered by an air-cooled 8.5 hp diesel engine. The system, shown in Figure 6.7.9, can generate pressurized cold water, hot water, and the mobile, 185 kg (1.1 m by 0.75 m by 0.75 m high) SCS 1200 DE can be set up and operated by one person.[1] The SCS 1200 DE supports the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

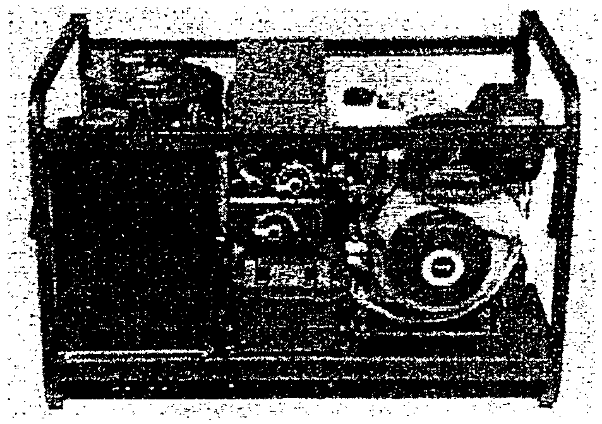


Figure 6.7.9. The Karcher SCS 1200 DE is a lightweight decontamination system designed to decontaminate skin, personal equipment, and exterior equipment. Photo reproduced with permission from Jane's Information Group.

6.7.10 Karcher SCS 1800 DE Decontamination System.

The SCS 1800 DE, shown in Figure 6.7.10, is decontamination system is designed to decontaminate skin, personal equipment, and exterior equipment (i.e. tracked and wheeled vehicles, aircraft). The SCS 1800 DE is a high-performance module, which employs mechanical technology. The SCS 1800 DE dispenses decontaminants, warm water, and other chemicals for decontamination. Depending on which decontaminants are utilized, the system may also employ either mechanical or chemical technologies. The system output can be varied from 300 to 1,800 liters/hour with a pressure range of 20 to 110 bar and is powered by a four-stroke diesel engine. The system can generate pressurized cold water, hot water, and hot steam with a maximum steam output temperature of 140°C, while the dry steam temperature is 200°C. The mobile, 410 kg (1.1 m by 0.85 m by 1.038 m high) SCS 1800 DE can be set up and operated by one person.[1] The SCS 1800 DE supports the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

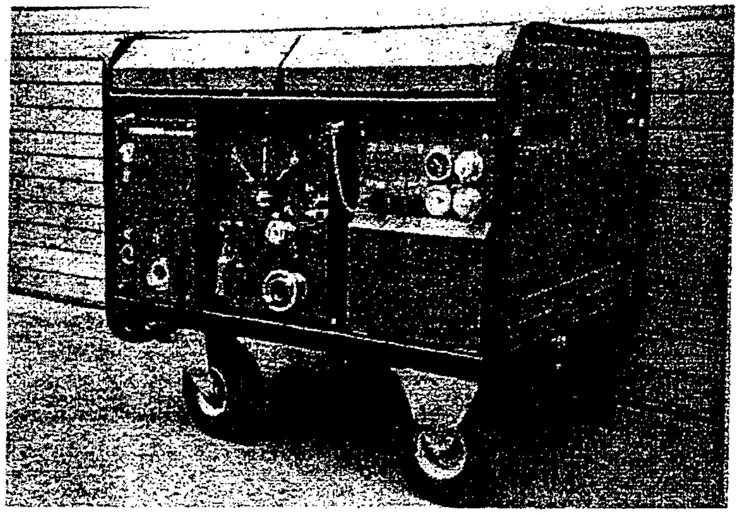


Figure 6.7.10. The Karcher SCS 1800 DE dispenses decontaminants, warm water, and other chemicals for decontamination. Photo reproduced with permission from Jane's Information Group.

6.7.11 Karcher M600 Decontaminant Mixer.

The M600 Decontaminant Mixer, in service with NATO forces, is designed to add and mix decontaminants using water jets for use with high-pressure cleaning systems. Depending on the decontaminant used, the M600, shown in figure 6.7.11, may employ either chemical or mechanical technologies. The M600 is equipped with a mixer, a 25 m hose, and a spray lance. The system is linked to a high-pressure system with a pressure hose and an electrical cable. The M600 holds up to 15 kg of decontaminant powder. The recommended flow rate for water is 10 liters/min with a powder addition rate of 2 kg/min. The mixer weighs 40 kg and is 560 mm long, 600 mm wide, and 840 mm high. The system can be powered by either a 12 V or a 24V supply.[1] The M600 Decontaminant Mixer is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

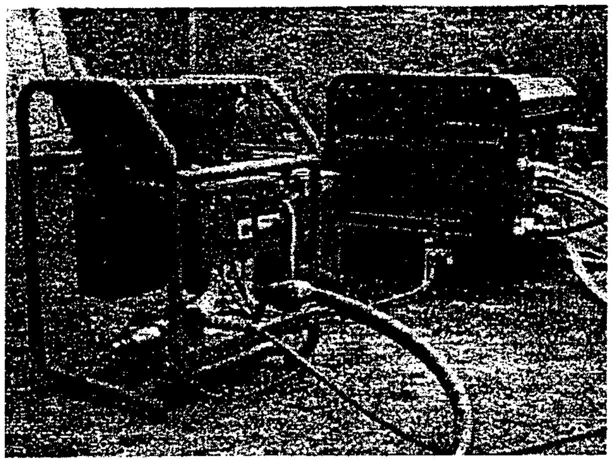


Figure 6.7.11. The M600 Decontaminant Mixer is designed to add and mix decontaminants using water jets for use with high-pressure cleaning systems. Photo reproduced with permission from Jane's Information Group.

6.7.12 Karcher Hot Air Generator FB 20.

The FB 20 is a hot air generator designed for the decontamination of clothing and other equipment placed inside a chamber or tent. The generator is in service with Canada, Denmark, Germany, Norway, Sweden, and U.S. armed forces. The FB 20, shown in Figure 6.7.12, employs low-temperature thermal technology. The generator has a heating capacity of 15kW/51,000 BTU and an air flow rate of 830 m^3/hour with a maximum output temperature of 90°C. The 78 kg generator (1.355 m by 0.46 m by 0.605 m high) consumes 2.2 liters/hour of fuel for the heater and requires 230 V 50 Hz electrical power.[1] The FB 20 Hot Air Generator is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

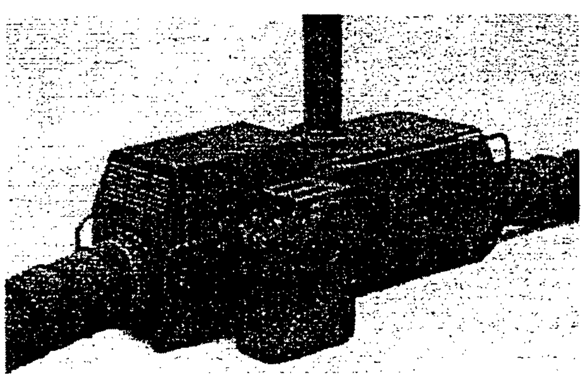


Figure 6.7.12. Karcher The FB 20 Hot Air Generator is designed for the decontamination of clothing and other equipment placed inside a chamber or tent. Photo reproduced with permission from Jane's Information Group.

6.7.13 Karcher AEDA1 Decontamination Equipment.

The AEDA1, in service with German forces, is designed to decontaminate sensitive and interior equipment. The system, shown in Figure 6.7.13, employs a combination of low-temperature thermal technology and mechanical technology. The AEDA1 is comprised of four components: an aerosol spray dispenser, a hot air generator, a remote-control unit, and a surface cleaning system.

Interior decontamination is conducted by spraying the contaminated surfaces with any decontaminant solution. The fine mist remains long enough in the air to decontaminate any contamination in the air. The decontaminant droplets also decontaminate material surfaces on contact. After the aerosol spray, the hot air generator is used to heat up the interior air and the interior equipment to neutralize any remaining agents. The hot air can reach temperatures as high as 150 °C and the flow rate of the air is approximately 3,000 m^3/h. A remote-control unit can be used to operate the hot air generator as well as to control the temperature of the air. The surface cleaning system resembles a vacuum cleaner and is used to remove any decontamination solution residue. The cleaner dispenses a liquid disinfecting solution and then vacuums the residue into a waste tank. The surface cleaning system has an output rate of 1 liter/min with a pressure or 1 bar.[1] The AEDA1 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	

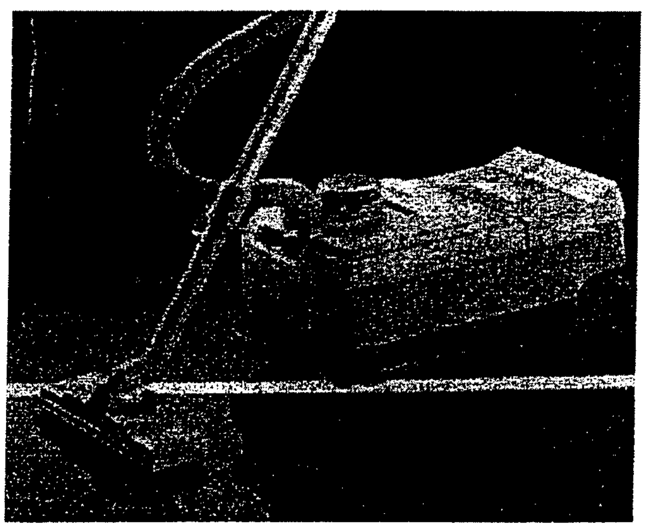


Figure 6.7.13. The Karcher AEDA1 is comprised of four components: an aerosol spray dispenser, a hot air generator, a remote-control unit, and a surface cleaning system for decontaminating sensitive equipment and interior equipment. Photo reproduced with permission from Jane's Information Group.

6.7.14 Karcher DT 60 Decontamination Tent.

The DT 60 Decontamination Tent is designed to decontaminate skin and personal equipment. The tent is currently in service with the Portuguese Air Force. The DT 60 employs low-temperature thermal technology in order to decontaminate personal equipment (i.e. clothing, protective equipment). The temperature of the hot gas stream is 140 °C. The double-walled tent is supported by an inflatable tubular frame, which is inflated using an included frame-mounted compressor. Should the tent undergo any loss in pressure, the compressor will re-inflate the supporting tubes automatically. Two people can erect the DT 60 in approximately 5 minutes and personnel enter the tent through a zip-fastened entrance flap.

The DT 60, shown in Figure 6.7.14, is capable of decontaminating up to 60 sets of clothing and equipment per hour. The tent weighs approximately 90 kilograms and is 5.58 meters in length, 2.4 meters in width, and 2.8 meters in height. The width of the entrance is 1.5 meters and the height of the entrance is 2 meters. The outside of the tent has a temperature resistance ranging from –30 to +80 °C, while the inside of the tent has a temperature resistance ranging from –30 to 140 °C.

The compressor with the carrying frame is 480 mm in length, 300 mm in width, and 300 mm in height. The power supply is 220 volts AC with a motor rating of 0.55 kW. The delivery rate for the decontaminant is 10.8 cubic meters/hour at a pressure of 200 mbar.[1] The DT 60 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

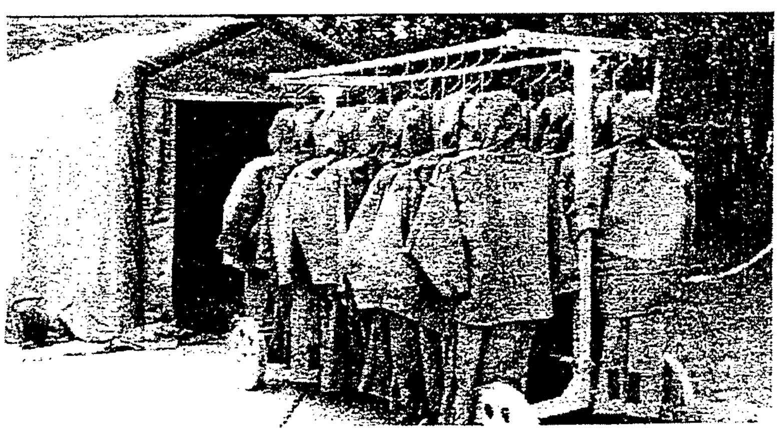


Figure 6.7.14. The Karcher DT 60 is capable of decontaminating up to 60 sets of clothing and equipment per hour. Photo reproduced with permission from Jane's Information Group.

6.7.15 Karcher Decont Tent.

The Decont Tent is designed for various decontamination tasks. The tent employs low-temperature thermal technology coupled with mechanical technology. The tent, shown in Figure 6.7.15, consists of an inflatable tubular frame, which can be assembled in 5 minutes utilizing an included manual air pump. The tent is used to shelter contaminated victims from inclement weather during decontamination procedures. Saturated steam (at temperatures up to 210 °C) or hot gas fed into the tent, via either the Karcher Multipurpose Decontamination System or a similar module, can be used to decontaminate personal clothing and equipment.

The tent tubular frame is equipped with a safety overflow valve. The tent tarpaulin has a watertight inner lining with a canvas groundsheet and is constructed of chemical agent resistant material. The tent is equipped with two hose connections to provide wastewater disposal. For stability, the tent is fastened securely by four ground loops and guy lines.

The tent weighs approximately 43 kilograms. The internal dimensions are 2 meters in length and width and 2.15 meters in height. The temperature resistance of the outside of the tent ranges from –30 to +80 °C, while the internal temperature resistance ranges from –30 to +140 °C.[1] The Decont Tent is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

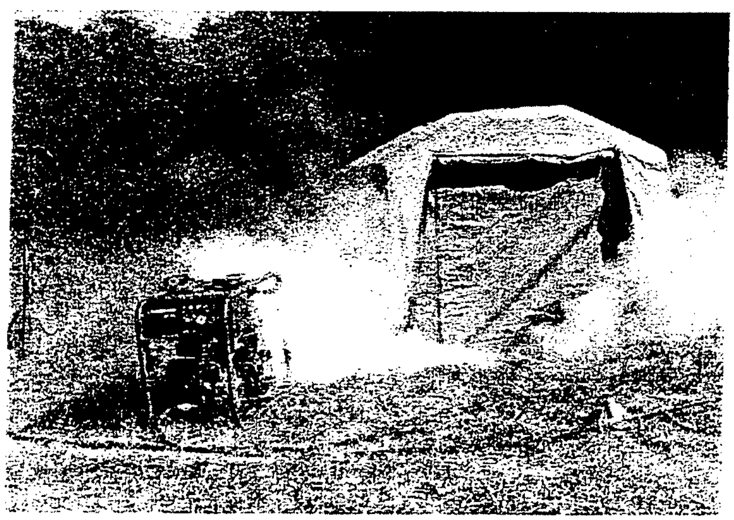


Figure 6.7.15. The Karcher Decont Tent is used to shelter contaminated victims from inclement weather during decontamination procedures.

6.7.16 Karcher Mobile Field Laundry CFL 60.

The CFL 60 is mobile field laundry system used to decontaminate personal equipment against both chemical and biological agents. The system is manufactured in Germany by Alfred Karcher GmbH & Company and is currently in service with the German and Norwegian armed forces. The system's primary function is to disinfect and launder contaminated garments. The CFL 60 employs both chemical and mechanical technologies to decontaminate items thoroughly.

The system, shown in Figure 6.7.16, is self-sufficient and requires only water and power, which is supplied by water reserves and an integral 125 kVA electrical generator, respectively. The CFL 60 is equipped with folding worktables, mangles, ironing boards, and handling containers. The CFL is a pre-programmed, push button system for easy operation. Washing agents and decontaminant solutions are added automatically.

The CFL 60 system contains an air conditioning unit for hot climates and an auxiliary heating system for cold climates, thus allowing the system to operate in all temperatures. The CFL 60 weighs approximately 10,000 kilograms and has a washing capacity of up to 60 kilograms per hour. The system is relatively quiet, requires minimal maintenance, and is easily transported.[1] The CFL 60 Mobile Field Laundry System is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

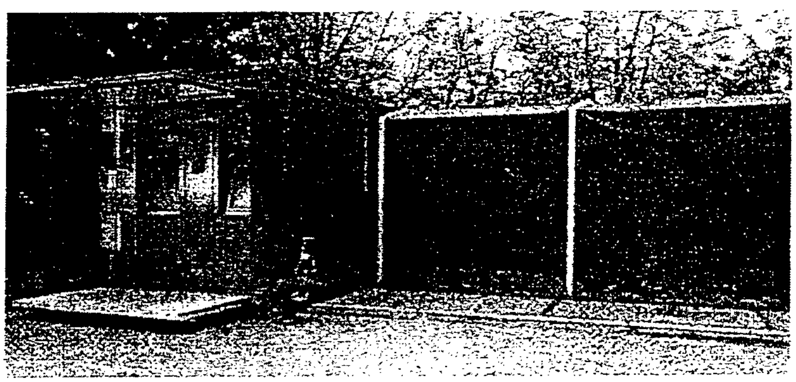


Figure 6.7.16. The Karcher CFL 60 Mobile Field Laundry System is used to decontaminate personal equipment against both chemical and biological warfare agents. Photo reproduced with permission from Jane's Information Group.

6.7.17 Karcher MultiPurpose Decontamination System (MPDS).

The MPDS is used to decontaminate skin and personal equipment, exterior equipment, and interior equipment. The system is currently in service with armed forces in Australia, Austria, Canada, Portugal, Sweden, United Kingdom, U.S., and NATO Headquarters. The MPDS is equipped with a high-pressure (60 bar) spray system and depending on the decontaminant used, the MPDS may employ either chemical or mechanical technologies. The MPDS is capable of dispensing cold water, hot water (80 degrees Celsius), hot steam (140 degrees Celsius), or dry steam (210 degrees Celsius). The MPDS is also equipped with a diesel engine, a burner, and a high-pressure water pump (maximum suction height of 5 meters).

Liquid decontaminants can be introduced into the water stream via the high-pressure pump at a rate up to 60 liters/hour. For easy usability, all MPDS operations can be controlled using an electrical control panel. The MPDS can also be used to provide water for showers in the field, steam explosives from munitions, or de-ice aircraft and missile systems. In addition, a sandblasting set is included to allow the removal of corrosion from equipment.

The MPDS, shown in Figure 6.7.17, weighs approximately 220 kilograms and is 1.25 meters in length, 0.575 meters in width, and 0.85 meters in height. The engine consists of a 4-stroke diesel that develops 5.6 horsepower at 3,000 rpm. The system operates over a temperature range of –30°C to +60°C.[1] The MPDS is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	✓
Large Area Decon	

Figure 6.7.17. The Karcher Multipurpose Decontamination System (MPDS) is capable of dispensing cold water, hot water (80 degrees Celsius), hot steam (140 degrees Celsius), or dry steam (210 degrees Celsius).

6.7.18 <u>Karcher Hot Air Generator FB 60 E</u>.

The FB 60 E, shown in Figure 6.7.18, is a hot air generator used to decontamination interior equipment, personal equipment, and exterior equipment. It is currently in service with the Australian, German, and U.S. armed forces. The FB 60 employs low-temperature thermal technology to decontaminate vehicles, aircraft, vessels, and personal equipment. The FB 60 E coupled with an interior decontamination extension set with special filters is used to decontaminate interior equipment.

The FB 60 E is comprised of a main fan and fuel pump, which are powered by a central 220-volt electric motor. Incoming air, drawn through the radial fan, is heated using a burner and heat exchanger. FB 60 E is capable of working at temperatures as low as –30°C. The system requires diesel, diesel-petrol, or kerosene fuels to operate. The FB 60 E can be used for a variety of applications other than decontamination (i.e. ventilating NBC decontamination stations, heating or cooling cabins, cockpits, tents, or shelters).[1] The FB 60 E is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	✓
Large Area Decon	

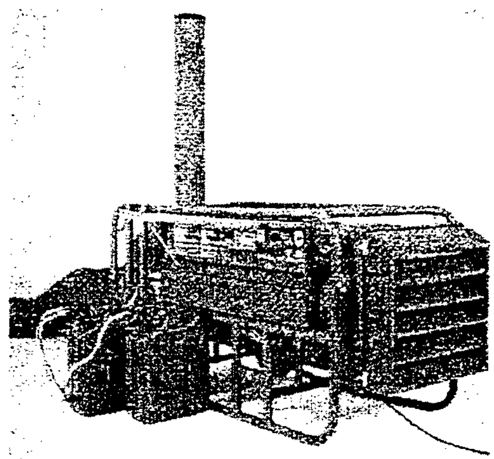


Figure 6.7.18. The Karcher Hot Air Generator FB 60 E is used to decontamination interior equipment, personal equipment, and exterior equipment. Photo reproduced with permission from Jane's Information Group.

6.7.19 <u>Karcher Decojet-Trailer Decontamination System</u>.

The Decojet-Trailer is mobile decontamination system used to decontaminate personal equipment, exterior equipment, and large areas. The system is currently in service in Australia, Austria, and Portugal. The Decojet-Trailer, shown in Figure 6.7.19, employ mechanical technology or chemical technology, depending on what decontaminant is utilized. The decontaminant employed is dispersed at high-pressures. The system has a flow rate up to 11,000 liters/hour of water, which allows the Decojet-Trailer to be used for a variety of applications other than decontamination (i.e. dousing fires, general maintenance, cleaning purposes).

The Decojet-Trailer carries all necessary decontamination chemicals, as well as 1000 liters of water, to allow for a limited degree of independent operation. The Decojet-Trailer is equipped with attached pumps, which extract water from sources (i.e. rivers, streams) up to a maximum suction height of 5 meters. The system also carries dry steam generators for further decon of contaminated materials. Steam temperatures can reach temperatures as high as 210 °C.

The Decojet-Trailer can decontaminate up to 150 soldiers per hour , 4 to 5 tanks/heavy trucks per hour (up to eight if they are chemical agent resistant), or 15 to 20 sets of clothing and personal equipment per hour. The system weighs 3,000 kilograms and is 5.16 meters in length, 2.45 meters in width, and 2.46 meters in height. The trailer has a ground clearance of 0.38 meters.[1] The Decojet-Trailer is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

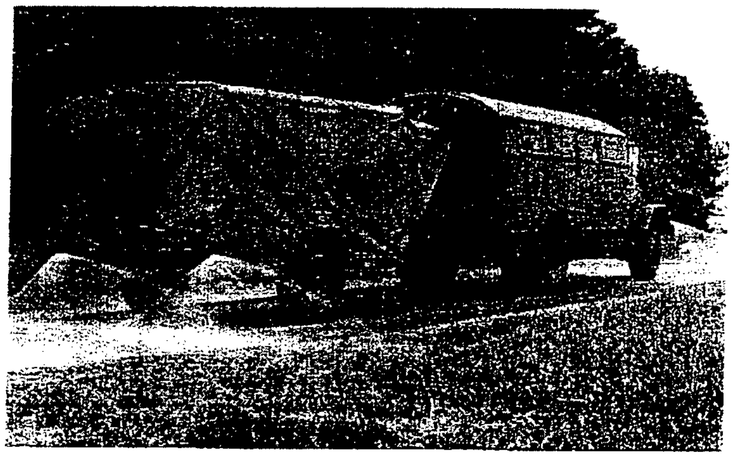


Figure 6.7.19. The Karcher Decojet-Trailer has a flow rate up to 11,000 liters/hour of water, which allows the system to be used for a variety of applications other than CB decontamination (i.e. dousing fires, general maintenance, cleaning purposes).

6.8 All Bann Enterprises Inc. - UNITED STATES.

6.8.1 M13 Portable Decontamination Apparatus (DAP).

The M13 Portable DAP is a portable system used to decontaminate exterior equipment (i.e. wheeled and track vehicles, crew-served weapons larger than 60 caliber (0.60 in/15 mm), towed artillery). The M13 is manufactured by All-Bann Enterprises, Incorporated and is currently in service with the U. S. Army. This equipment employs chemical technology and can be either vehicle-mounted or man-portable.

The M13, shown in Figure 6.8.1, is comprised of a disposable container filled with 14 liters of DS2 decontaminating agent (or can be replaced with any other decontaminating agent), an accessory container holder, a manual in-line pump, one to two wand sections, and a disposable synthetic filament polypropylene brush. The accessory container provides storage for all M13 components.

The specifications associated with the M13 DAP include a volume of 14 liters, a filled weight of 24.5 kilograms, and an empty weight of 10.9 kilograms. The coverage provided by a filled tank is approximately 112 square meters. The M13 container is approximately 355.6 mm in length, 168.4 mm in width, and 476.3 mm in height. The M13 can be used over a temperature ranging from -31.7 to +49°C.[1] The M13 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.8.1. The M13 Portable DAP, manufactured by All-Bann Enterprises, is a portable system used to decontaminate exterior equipment. Photo courtesy of Sgt. Michael O'Hern -Retired, U.S. Army.

6.8.2 Decontaminating Apparatus, Portable, DS2, ABC-M11.

The ABC-M11, shown in Figure 6.8.2, is a portable decontaminating apparatus used to decontaminate exterior equipment (i.e. military vehicles, crew-served weapons). The system is currently in service with the U.S. Army and Israeli armed forces. The ABC-M11 employs chemical technology. This item is carried on a rack on nearly all military vehicles produced in the U.S. The equipment is equipped with a filled nitrogen pressure cartridge. However, before use, the container must be filled with DS2 decontaminating agent. The M11 is functioned by removing the seal-retaining pin. After removing the pin, the handle is lifted to puncture the pressure can, dispersing the DS2. The ABC-M11 has an optimum range of about 2 meters and can cover approximately 42 m^2.

There are three models currently available, the M11, the M11 Stretch, the M11 Super Stretch. The three models differ only by container volume, the M11 has a filled volume of 1.26 liters, the M11 Stretch has a filled volume of 1.5 liters and the M11 Super Stretch has a filled volume of 2.66 liters. All three models can withstand temperatures ranging from –31.7 to +49 °C. This system is also available with the M11 A/G dry sorbent dispenser. The M11 A/G sprays the AMBERGARD™ XE-555 powder.[1] The detailed specifications for this piece of equipment are provided below:

Model	M11	M11 Stretch	M11 Super Stretch
Container Volume	1.42 liters	1.67 liters	2.66 liters
Filled Volume	1.26 liters	1.5 liters	2.5 liters
Weight Filled	3.42 kg	3.77 kg	6.34 kg
Weight Empty	2.19 kg	2.31 kg	3.07 kg
Diameter	139.7 mm	139.7 mm	139.7 mm
Height	361.9 mm	361.9 mm	525 mm
Duration of Charge	30 sec	35 sec	60 sec
Coverage	125 square meters	150 square meters	248 square meters

The M13 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.8.2. The ABC-M11, used by U.S. and Israeli armed forces, is a portable decontaminating apparatus used to decontaminate exterior equipment. Photo courtesy of Sgt. Michael O'Hern - Retired, U.S. Army.

6.9 Anachemia Canada Inc. - CANADA.

6.9.1 <u>Skin Decontaminant Lotion</u>.

This Skin Decontaminant Lotion is used to decontaminate on contact skin and personal equipment. The lotion, manufactured in Canada by Anachemia, is currently in production. The lotion employs chemical (oxidation) technology and is effective against chemical agents, such as mustard (H), nerve agents, and Lewisite (L).

The lotion, shown in Figure 6.9.1, is supplied in a sealed barrier material pouch, under a layer of inert gas. The pouches are 155-mm long, 155-mm wide, and 50-mm high. Each pouch contains a towelette impregnated with 45 ml of lotion. The pouches are supplied in sets of four and can be opened while wearing gloves. Towelettes are wiped over the contaminated area and then wiped off after use. The lotion can be used in temperature ranges from –10 to +50 °C. The lotion should only be used on the skin and should not come in contact with the eyes.[1] The Skin Decontamination Lotion is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

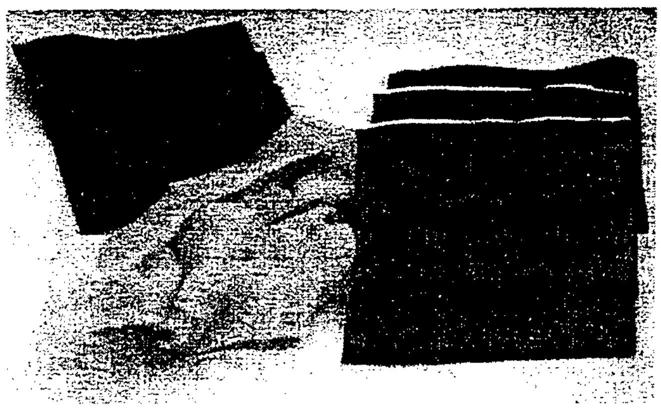


Figure 6.9.1 Anachemia's Skin Decontaminant Lotion is used to decontaminate on contact skin and personal equipment. Photo reproduced with permission from Jane's Information Group.

6.10 Applied Surface Technologies – UNITED STATES.

6.10.1 <u>K1-05 Standard Unit</u>.

The K1-05, manufactured commercially in the U.S. by Applied Surface Technologies, is designed to clean sensitive equipment. The K1-05 employs mechanical technology (high-pressure CO_2), which uses CO_2 to remove micron and sub-micron particles from surfaces at high efficiencies and also removes hydrocarbon based contamination. The CO_2 snow cleaning is nondestructive and nonabrasive. The process leaves no residue on the surface of the item nor does it produce any chemical waste. The K1-05 unit addresses both the general and critical cleaning problems.

The unit, shown in Figure 6.10.1, comes with either a 5 or 10 foot flexible stainless steel PTFE lined hose, a CGA320 cylindrical fitting, an on/off gun, an optional 0.5 micron sintered stainless steel filter, a 0-2000 psi pressure gauge, and two nozzles. One nozzle is an FEP polymer, the other nozzle is a stainless steel, and both have 16 mil diameter orifices. A brass nozzle can also be substituted for the stainless steel nozzle. A 24-volt DC or a 120-volt AC solenoid control valve can be supplied in place of the on/off gun. The standard units can also be equipped with the narrow 1/16-inch outer diameter by using either a .010, .020, or .030 thousandth of an inch inner diameter tube. The K1-05 Standard Unit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	
Large Area Decon	

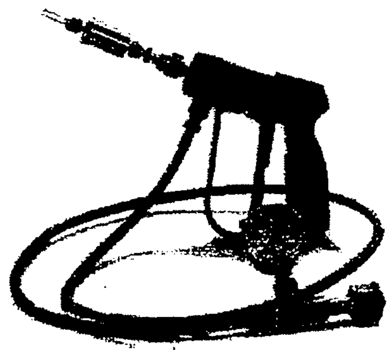


Figure 6.10.1. Applied Surface Technologies K1-05 is designed to clean sensitive equipment using high-pressure CO_2 technology to remove micron and sub-micron particles from surfaces. Photo courtesy of Applied Surface Technologies.

6.10.2 K4-05 High Purity Unit.

The K4-05 high purity unit, shown in Figure 6.10.2, is also designed to clean sensitive equipment. This system employs mechanical technology (high-pressure CO_2), which uses CO_2 to remove micron and sub-micron particles from surfaces at high efficiencies and also removes hydrocarbon based contamination. The CO_2 snow cleaning is nondestructive and nonabrasive. The process leaves no residue on the surface of the item nor does it produce any chemical waste. The K4-05 unit addresses both the general and critical cleaning problems. These units come with either a 5 or 10-foot flexible stainless steel PTFE lined hose, a CGA320 cylindrical fitting, two nozzles, and a 0.01 micron filter. All fittings for this unit are compression fittings as opposed to NPT fittings. An electropolished 24 VDC or 120 VAC solenoid valve (with compression fittings) can be substituted for the 90-degree on/off valve. The K4-05 High Purity Unit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	
Large Area Decon	

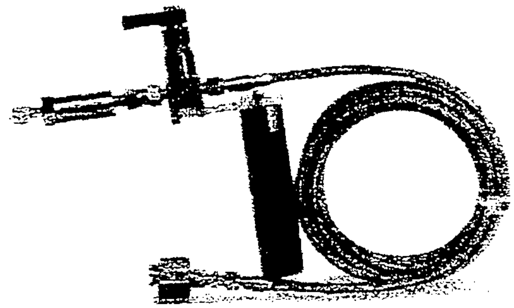


Figure 6.10.2. Applied Surface Technologies K4-05 High Purity Unit. Photo courtesy of Applied Surface Technologies.

6.10.3 Snow Motion.

The Snow Motion is a fully automated CO_2 snow cleaning workstation used to clean sensitive and interior equipment. It is commercially available in the U.S. The system employs mechanical technology (high-pressure CO_2). Snow Motion, shown in Figure 6.10.3, is used to clean laser filters, visible lenses, mirrors, wire bond pads, ceramics, metals, and wafers. Contamination is lifted off the surface and partially absorbed into the CO_2 stream. The Snow Motion, if used for decontamination, would only remove the contamination. An additional procedure would be necessary to decontaminate the agent.

The station features four axis motion (x,y,z,rotary) with a user friendly programming interface. Cleaning procedures can be saved as programs, which can be saved, recalled, and later edited with a keyboard and display interface located on front panel. The nozzle is made of stainless steel, which produces a near sonic stream of CO_2 with a coaxial flow of nitrogen to reduce moisture. Moisture will inhibit the cleaning process. The system is also equipped with inline gas filters, which are fitted just prior to the nozzles. The unit is operated at temperatures ranging from 20 to 30°C and the CO_2 stream can be as cold as –60 °C. The basic model weighs 500 pounds and is 1 m long, 1 m wide, and 2 m high. However, the unit could be custom made to hold a 14 foot long item. The Snow Motion is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	

Figure 6.10.3. Applied Surface Technologies Snow Motion is a fully automated CO_2 snow cleaning workstation used to clean sensitive and interior equipment. Photo courtesy of Applied Surface Technologies.

6.11 Bachmann SA - FRANCE.

6.11.1 Chemical Decontamination Glove mle F1.

The Chemical Decontamination Glove mle F1, shown in Figure 6.11.1, is a fingerless, olive green glove made from natural fibers used to decontaminate skin and personal equipment. The glove is manufactured in France by Bachmann and is in service by the French Armed Forces. The glove employs sorbent technology. One side of the glove has decontaminating powder (such as fuller's earth) behind a fine mesh, while the other side is a cotton sponge fabric. The powder is patted onto the exposed surface and then wiped off with the sponge fabric. The gloves are issued in sealed plastic bags measuring 120 x 200 mm and 20 mm thick and weighs 140 grams. The glove is capable of decontaminating an area of 9 m^2. The Chemical Decontamination Glove is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.11.1. Bachmann's Chemical Decontamination Glove mle F1 is a fingerless, olive green glove made from natural fibers used to decontaminate skin and personal equipment. Photo reproduced with permission from Jane's Information Group.

6.12 Birchmeier & Cie AG - SWITZERLAND.

6.12.1 INTER-CB Decontamination Apparatus E-85.

The INTER-CB decontamination apparatus E-85 is a portable and rugged hand pump device used to spray CB decontamination solutions to decontaminate exterior equipment. The system is manufactured in Switzerland by Birchmeier & Cie AG and has been in service with the Swiss Army since 1985. The E-85, depending on which decontamination solution is utilized, may employ either chemical or mechanical technologies. The E-85's plastic body, shown in Figure 6.12.1, resembles a fire extinguisher and utilizes high-pressure spray technology. It has an internal volume of 1.5 liters and is capable of decontaminating an area of about 10 m^2. The apparatus needs little to no maintenance and no one specific decontamination solution is required.[1] The INTER-CB decontamination apparatus E-85 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.12.1. Birchmeier & Cie's AG INTER-CB decontamination apparatus E-85 is a portable and rugged hand pump device used to spray CB decontamination solutions to decontaminate exterior equipment. Photo reproduced with permission from Jane's Information Group.

6.13 Burch MFG. Co. Inc – UNITED STATES.

6.13.1 Burch Portable Decontamination Booth.

The Burch Portable Decontamination Booth is a collapsible decontamination booth used to confine contained water from an emergency wash down within an industrial strength, 22-oz, vinyl-coated nylon liner. The booth, commercially manufactured in the U.S. by Burch Manufacturing Company, measures 4 feet long, 4 feet wide, and 6 feet high. The booth is designed for on-site use at a hazardous materials incident, fire, or any industrial plant that handles chemicals. The booth is used in conjunction with decontamination showers, which are not included. Waste water drains through a 1.5-inch outlet into any standard handling receptacle. The booth has a steel framework and can be assembled in minutes. The booth weighs 60 pounds and can be easily transported. The Burch Portable Decontamination Booth is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.14 CKD Blansko, PLC – CZECH REPUBLIC.

6.14.1 ST-T815 NBC Decontamination Vehicle.

The ST-T815 NBC Decontamination Vehicle, shown in Figure 6.14.1, is a vehicle used to decontaminate exterior equipment, large areas, and skin and personal equipment. The ST-T815 is manufactured in Germany by CKD Blansko and is in service with the Czech Army. The vehicle sprays decontamination solutions and employs both chemical and mechanical technologies. The vehicle is equipped with two 750-liter fuel tanks, two 3,000-liter agent tanks, and one 1,500 liter water tank. The ST-T815 is equipped with a 192 kW PG-160 steam generator, two heavy-duty pumps and an electrical generator driven by a gas turbine. The vehicle is also equipped with spray bars, hoses, and a hydraulic arm behind the cab, which carries a work platform which provides access to locations which might otherwise be inaccessible.

The ST-T815 has the capability to decontaminate 20 vehicles/hour using hand-held hose lines, or it can be connected to a spray system, that would enable up to 50 vehicles/hour to be decontaminated. Approximately 360 m^2 surface area can be decontaminated in one hour or 90 m^2 of an aircraft exterior/hour. The system can be operated by a remote control panel that can be carried on a soldier's shoulder. The panel duplicates all the system controls inside the vehicle cab.

The ST-T815 offers additional services other than decontamination. It can be used to douse fires or to heat or defrosting equipment such as aircraft. The ST-T815 weighs 35 tons and is only produced in small numbers.

The ST-T815 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

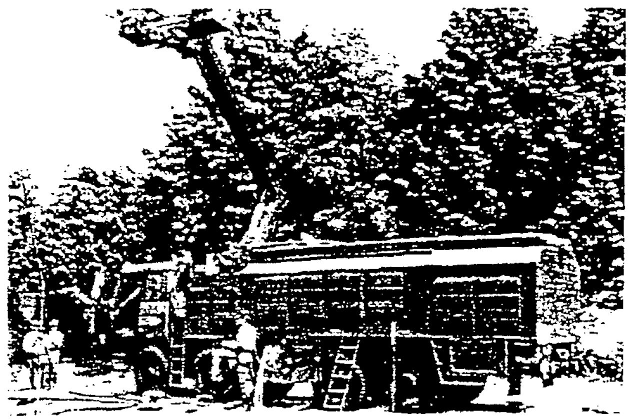


Figure 6.14.1. CKD Blansko's ST-T815 NBC Decontamination Vehicle is used to decontaminate equipment exteriors, large areas, and skin and personal equipment. Photo reproduced with permission from Jane's Information Group.

6.15 Container Products Corporation – UNITED STATES.

6.15.1 <u>The Kelly Decon System</u>.

The Kelly Decon System, shown in Figure 6.15.1, is a unique, patented machine designed to decontaminate large surfaces. The system is commercially available in the U.S. and is manufactured by Container Products Corporation. The Kelly Decon System employs mechanical technology and disseminates superheated water at high-pressures. The system can operate at temperatures up to 300°F. The high solubility of the superheated water spray dissolves and suspends the contamination and allows the Kelly System to remove "fixed" contamination from porous surfaces by the high velocity, positive displacement vacuum system. The system is composed of four main components:

- Main Superheated Water Supply Unit
- Positive Displacement Vacuum Unit
- Demister/HEPA Filter Unit
- Cyclone Liquid Separator

The Kelly system can be used on porous exterior surfaces such as asphalt, bare concrete, and wood. The system has coverage rates of 50 ft^2 per minute. Up till now the system has been used to decontaminate radioactive contamination, however, the system has the potential to serve CB decontamination. The Kelly system is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

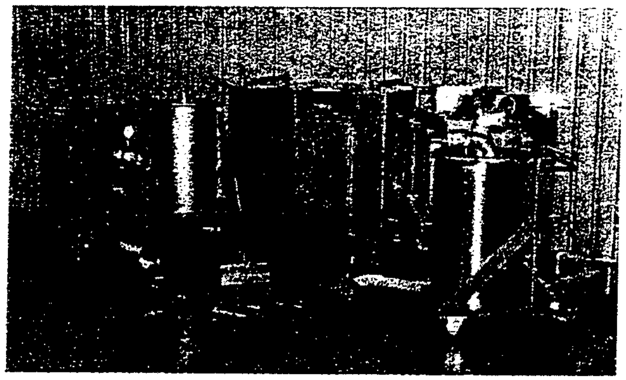


Figure 6.15.1. The Kelly Decon System is a unique, patented machine designed to decontaminate large surfaces. Photo courtesy of Container Products Corporation.

6.15.2 Decontamination Glove Booths.

Container Products Corporation manufactures a series of commercially available high-pressure decontamination booths. The decontamination units are designed for the decontamination of hand tools and other large heavy items. The booths employ mechanical technology, and they disperse high-pressure water sprays over contaminated equipment. The booths have an adjustable output pressure to 3,000 psi at 4 gpm. The booths, shown in Figure 6.15.2, are made from stainless steel construction and are equipped with a chemical solution injection system. The water supply can be heated to a temperature range of 100°F to 300°F. The Decontamination Glove Booth is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

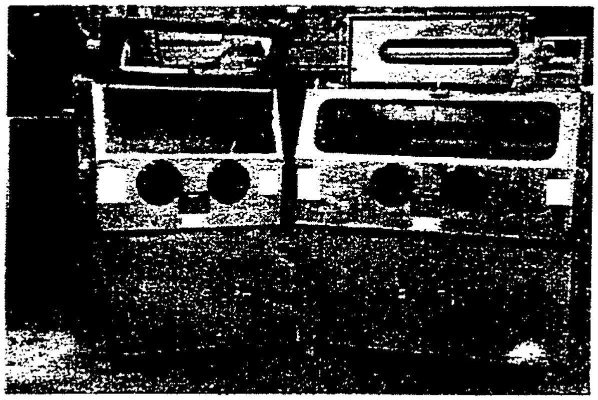


Figure 6.15.2. Container Products Corporation Decontamination Booths employ water technology and disperse high-pressure water sprays over contaminated equipment. Photo courtesy of Container Products Corporation.

6.16 Crest Ultrasonics – UNITED STATES.

6.16.1 The Optimum Console.

The Optimum Console, shown in Figure 6.16.1, is a versatile precision cleaning system. It is commercially available in the U.S. and is manufactured by Crest Ultrasonics. The system employs mechanical technology (ultrasonic) and is available in aqueous or semi-aqueous process versions. The system is made from rugged, stainless steel and is available in 3, 4, or 5 stage wash station designs. Stand tank sizes range from 10''L x 14''W x 10''D to 24''L x 36''W x 20'' D deep. The three-station Optimum console is a wash-rinse-dry system designed for most general cleaning applications. The four-station wash-rinse-rinse-dry system is ideal for precision cleaning applications at the microscopic level. The five-station wash-wash-rinse-rinse-dry is configured for semi-aqueous cleaning applications.

The Ultrasonic Wash provides high intensity heated ultrasonic wash. Filtered recirculation with overflow weir aids in removing oil and particulate contaminants. The wash is followed by a Heated Ultrasonic Rinse, which provides a two stage reverse flow cascade rinse with spray-over immersion, conserving space and water usage. The last stage, the High Efficiency Recirculating Hot Air Dryer, quickly dries parts using compressed air.

The Optimum Console is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

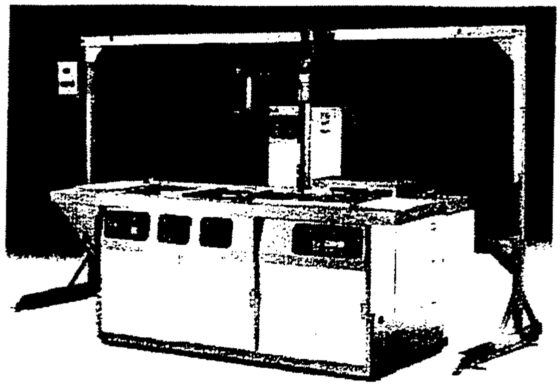


Figure 6.16.1. Crest Ultrasonics Optimum Console is a versatile precision cleaning system employing ultrasonic technology and is available in aqueous or semi-aqueous process versions. Photo courtesy of Crest Ultrasonics.

6.16.2 Hospital Line of Ultrasonic Cleaners.

The HAL Series, shown in Figure 6.16.2, is a hospital line of ultrasonic cleaners used to clean hospital instruments completely before they are subjected to disinfection and sterilization. The HAL Series is available commercially in the U.S. and is manufactured by Crest Ultrasonics. The systems employ mechanical technology (ultrasonic) in order to clean personal equipment. The consoles are available in 11 gallon, 15 gallon, and 20 gallon sizes. The systems are easily operated with a push of one button. The systems can be sued in conjunction with cleaning solutions in order to obtain optimal cleaning efficiencies. The systems have operating temperatures between 110°F-140°F. The Hospital Line of Ultrasonic Cleaners is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

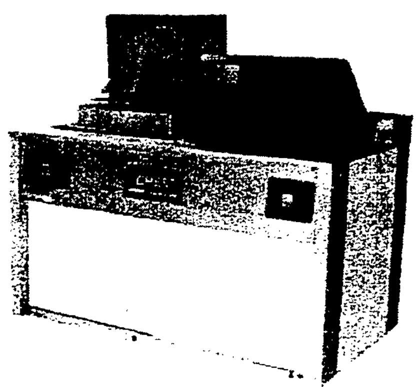


Figure 6.16.1. Crest Ultrasonics HAL Series is a hospital line of ultrasonic cleaners used to clean hospital instruments completely before they are subjected to disinfection and sterilization.

6.17 Cristanini SpA - ITALY.

6.17.1 SANIJET C921 Decontamination System.

The SANIJET C921 is a decontamination system utilized to decontaminate exterior equipment. The system is manufactured in Italy by Cristanini SpA and is in service with French, Italian, Korean, and Spanish armed forces. The SANIJET C921 employs mechanical technology. The SANIJET C921, shown in Figure 6.17.1, is powered by an air-cooled 10 hp diesel engine that drives a water pump capable of delivering cold or hot water (up to 95°C), steam (120°C), or dry steam (190°C). The system delivers hot water at 90 bar and 14 liters/minute, steam at 20 bar and 550 kg/hour and dry steam at 20 bar and 300 kg/hour. The C921 is capable of suctioning water to a height of 5 m and disperses water using spray lances. The C921 weighs 230 kg and is 0.85 m long, 0.85 m wide, and 0.80 high.[1] The SANIJET C921 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

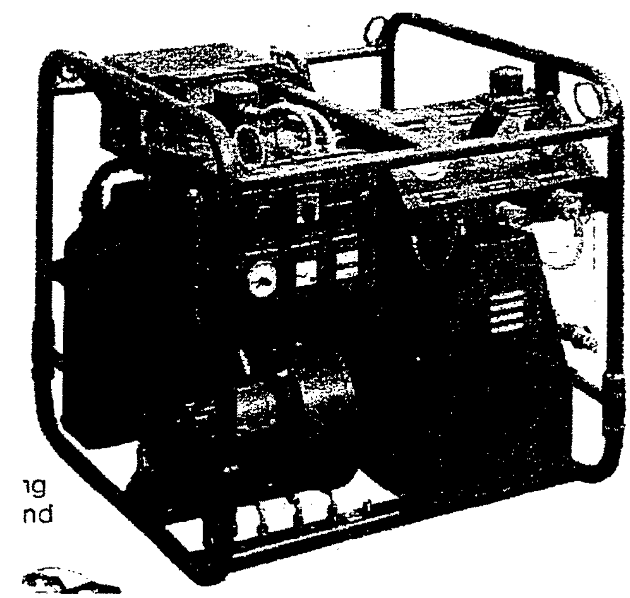


Figure 6.17.1. The Cristanini SANIJET C921 is powered by an air-cooled 10 hp diesel engine that drives a water pump capable of delivering cold or hot water, steam, or dry steam.

6.17.2 Trailer C90-120-2 MIL Decontamination System.

The trailer decontamination system, shown in Figure 6.17.2, is designed for the decontamination of vehicles, equipment, personnel, and terrain. The system is in service with Italian and NATO forces. The trailer decontamination system employs mechanical technology and disseminates water at high-pressures. The C90-120-2 MIL is a two lance system powered by an air-cooled 32 hp diesel engine that drives a water pump. The lances can deliver low pressure shower water (6,000 liters/hour), hot water (1,920 liters/hour at 90 bar), and wet or dry steam (800 to 1,200 kg/hour at 20 bar). The system is equipped with a 1,500-liter tank and can be removed from a trailer base and mounted on skids. The system weighs 3,100 kg and is 4.55 m long, 2.2 m wide, and 2.7 m high and is air transportable.[1] The C90-120-2 MIL is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

Figure 6.17.2. The Cristanini trailer decontamination system employs water technology and disseminates water at high-pressures.

6.17.3 SANIJET Gun.

The SANIJET gun is designed to decontaminate exterior equipment. The SANIJET gun, shown in Figure 6.17.3, employs chemical technology (primary) and mechanical technology (secondary). The system is designed to execute every operation in the decontamination process, including pre-washing with high-pressure cold water, mixing and delivering decontaminant emulsion, and rinsing with hot water. The SANIJET gun uses the BX24 decontamination powder in rechargeable cartridges that mount on the top of the unit. The SANIJET gun includes a shoulder strap and maintenance tools that are stowed inside the front handle.[1]

The SANIJET gun filled with BX24 decontaminant was tested at Dugway Proving Grounds (DPG) from 14 September 1998 to 20 September 1998 using thickened GD (TGD), VX, and HD. Testing involved spiking two inch CARC-coated and bare metal disks with agent (wait 30 min), rinsing with water (wait 30 min), applying decontaminant (wait 30 min), and then a final rinsing with water. The SANIJET with BX24 performed with acceptable results. The SANIJET gun is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

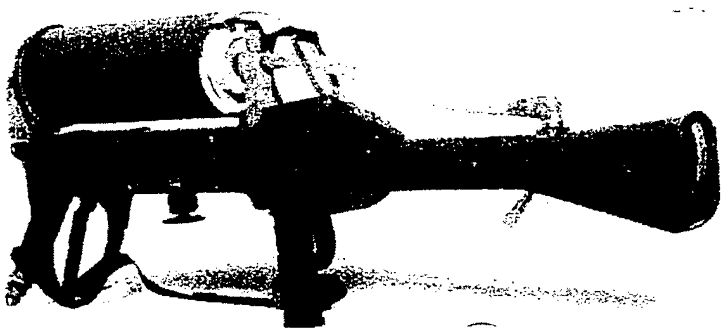


Figure 6.17.3. The Cristanini SANIJET Gun is designed to execute every operation in the decontamination process, including prewashing with high-pressure cold water, mixing and delivering decontaminant emulsion, and rinsing with hot water. Photo courtesy of Cristanini.

6.17.4 SANIJET 3000-3 Containerized Decontamination.

The SANIJET 3000-3 containerized decontamination device is designed for the decontamination of personnel, clothing, vehicles, and other equipment. The apparatus is manufactured by Cristanini SpA of Italy and is in service in the U.S. The system employs mechanical technology, however, it also has chemical technology (microemulsions) capabilities. The SANIJET 3000-3, shown in Figure 6.17.4, consists of a single 20 ft/6.096 m ISO standard container that encloses a fully self-contained unit for decontamination. The container uses an NBC filtration system to produce an internal overpressure. The system includes a 1,000 m^3/hour and operates over a temperature range from -32°C to 52°C. The water tank has a 2,000-liter capacity and is supplied by a pump and filter system capable of collecting water from various sources.

The container is divided into five compartments: control room, showers, garment decontamination, an access/exit area, and an engine compartment. The shower entrance area is kept at a 25 mbar overpressure, while the shower is kept with a differential pressure of 30 mbar. The shower provides 18 liters/min of water (with or without detergents) from 20°C to 40°C. After the shower, personnel move to the control room for drying and dressing. For decontamination of vehicles and equipment, the system includes 2 water spray lances, a foam spray lance, and a vapor lance with hoses for external use. The water lances operates at 110 bar with an 18-liter/minute flow. The foam application lance operates at 35 bar with a 10-liter/minute flow. Garments are decontaminated in a compartment equipped with racks, hangers, bags, and a sump for wastewater collection. Vapor is supplied at 16 bar with a 10-liter/minute flow rate between 120°C and 140°C.[1] The SANIJET 3000-3 Containerized Decontamination is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

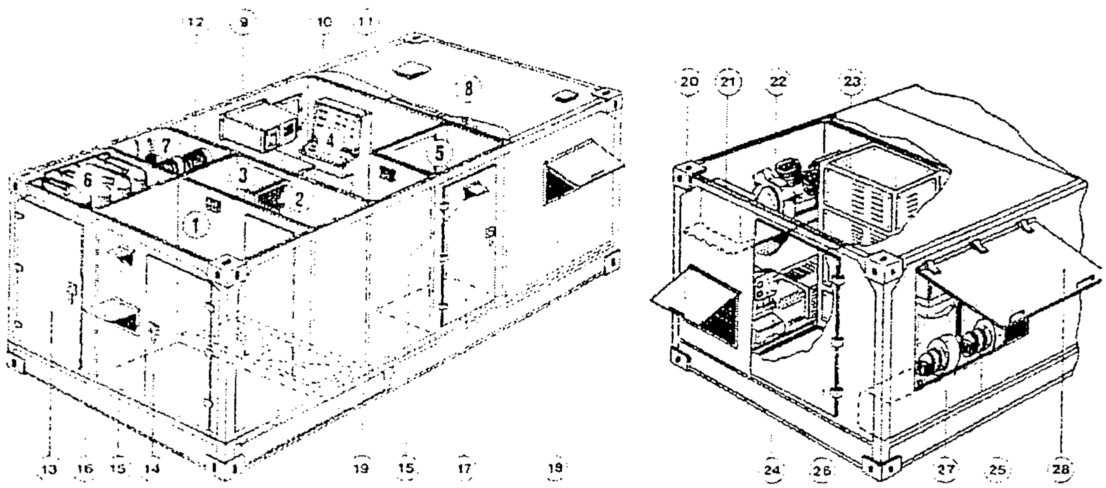


Figure 6.17.4. The Cristanini SANIJET 3000-3 containerized decontamination device is designed for the decontamination of personnel, clothing, vehicles, and other equipment. Photo reproduced with permission from Jane's Information Group.

6.17.5 Decontamination and Shower Tent.

The Decontamination and Shower Tent, shown in Figure 6.17.5, is designed for the decontamination of personnel. The system employs mechanical technology and disseminates water at high-pressures. The unit is available in two sizes (6m x 9m and 6m x 12m). It has a capacity of 60 to 250 personnel per hour. The system can be provided with a waste-water sump and an air heating system to heat the interior or blow dry personnel.[1] The decontamination and shower tent is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

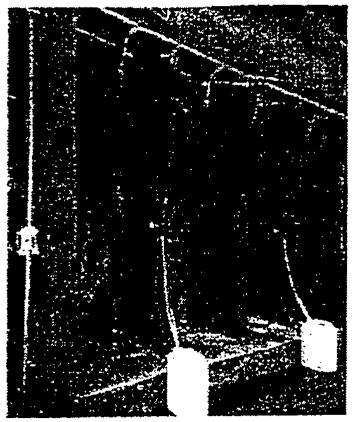


Figure 6.17.5. The Cristanini Decontamination and Shower Tent.

6.18 Cryo*kinetics*.

6.18.1 <u>Delta V-1 Dry Ice Surface Cleaning System</u>.

The Delta V-1 Dry Ice Surface Cleaning System, shown in figure 6.18.1.1, employs mechanical technology and is designed as an environmentally safe alternative to the many surface cleaning methods currently available. The system is commercially available in the United States and is manufactured by Cryo*kinetics*. The Delta V-1 is a portable, easy to operate system requiring no electrical power. This system employs small particles of dry ice in conjunction with high air pressure as the primary cleaning method. The dry ice particles convert from a solid to a gas upon impacting the surface being cleaned. This system is a non-waste generating unit. Rice, plastic beads, glass beads, etc. can be used for more aggressive surface preparation requirements.

The Delta V-1 weighs approximately 85 pounds and is 16 inches long, 12 inches wide, and 24 inches high. The system uses from 0 to 3 pounds of dry ice per minute and has a dry ice capacity of 25 pounds. The Delta V-1 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	
Large Area Decon	

Figure 6.18.1.1. The Delta V-1 employs pressurized CO_2 in order to clean sensitive equipment. Photo courtesy of Cryo*kinetics*.

6.19 Cryogenesis – UNITED STATES.

6.19.1 Ice Gun.

The Ice Gun, shown in Figure 6.19.1, is designed to decontaminate sensitive and interior equipment. The Ice Gun is commercially available in the U.S. and is manufactured by Cryogenesis. The gun employs mechanical technology (high-pressure CO_2) with controlled air speed allowing the dry ice to be accelerated to subsonic or supersonic speeds (in excess of 1300 feet per second). The gun's operating range is between 40 psi and 350 psi and is able to be elevated 50 ft to 60 ft. The ice pellets range from 100 microns to ¼ inch in diameter. The Ice Gun is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	

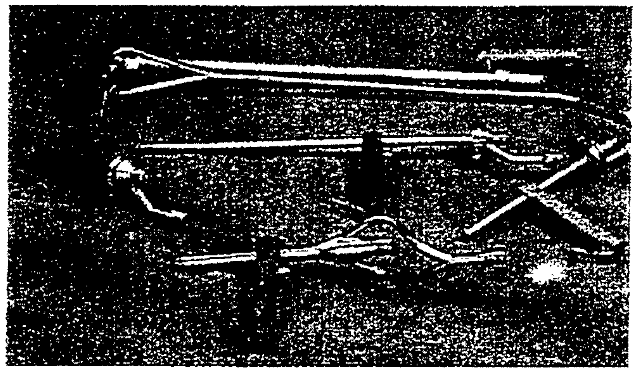


Figure 6.19.1. The Cryogenesis Ice Gun is designed to decontaminate sensitive and/or interior equipment.

6.19.2 Booth.

The Booth is a fully automated cleaning system that is commercially available in the U.S. The system, shown in Figure 6.19.2, employs mechanical technology (high-pressure CO_2) to clean equipment. The booth is equipped with an "x-y" translation and rotation table coupled with a stationary ice gun. Contaminated equipment is placed inside the booth on a table that rotates the equipment around as the ice gun disperses ice pellets to clean the equipment. Contaminated equipment is cleaned in one step. The cleaning system is housed in a soundproof booth. The Booth is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

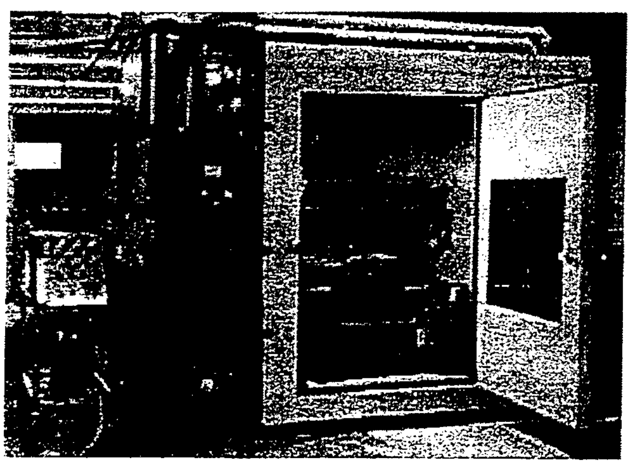


Figure 6.19.2. The Cryogenesis Booth is a fully automated cleaning system is designed to decontaminate equipment.

6.20 Deutsche Aerospace - GERMANY.

6.20.1 Mobile NBC Decontamination Semi-Trailer.

The Mobile NBC Decontamination Semi-Trailer is a 13-m long facility used to decontaminate personal equipment (i.e. clothing). The trailer, shown in Figure 6.20.1, is manufactured in Germany by Deutsche Aerospace and is in service with the German armed forces. The system employs both low-temperature thermal and mechanical technology. Contaminated equipment is hung on a conveyor system, that carries the equipment into a heated area where fans blow contaminated particles away for 30 minutes. The equipment then undergoes superheated steam at 170 °C. Finally, the equipment is subjected to a foam treatment and then rinsed of any remaining residue using spray pipes. The system can decontaminate up to 63 protective suits per hour. The system is equipped with an 800-liter water tank and is powered by a 6.5 kVA generator.[1] The Mobile NBC Decontamination Semi-Trailer is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

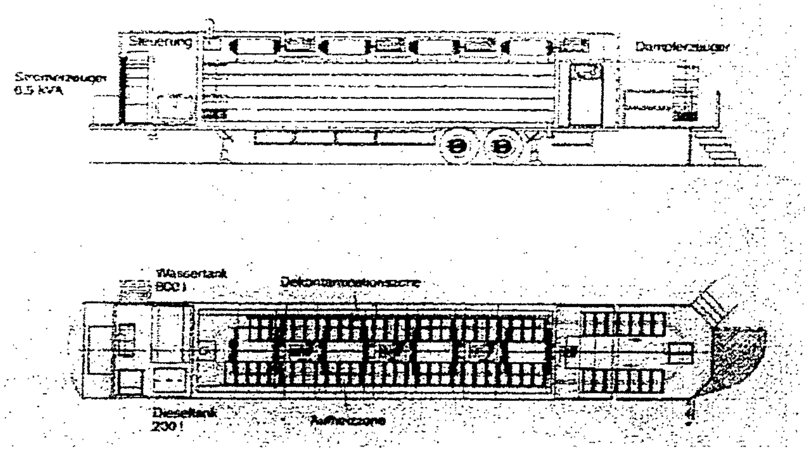


Figure 6.20.1. Deutsche Aerospaces Mobile NBC Decontamination Semi-Trailer is a 13-m long facility used to decontaminate personal equipment (i.e. clothing).

6.21 DEW Engineering and Development Limited - CANADA.

6.21.1 NBC-DEWDECON-2L.

The NBC-DEWDECON-2L decontamination device, shown in Figure 6.21.1, is a lightweight man-portable system designed to decontaminate exterior equipment. This system is manufactured in Canada by DEW Engineering and Development Limited and is currently in service in the Middle East. The NBC-DEWDECON-2L employs chemical technology and is used to disseminate DS2 decontaminating agent in a controlled spray to remove chemical warfare agents from contaminated surfaces. The DEWDECON-2L is a smaller version of the DEW 3-liter unit and shares many interchangeable parts. The DEW 2-liter device uses nitrogen cartridges as the primary method of pressurization, with an attached hand pump as back-up. The device, when stowed in its mounting bracket measures 150 mm in width, 160 mm in depth, and 440 mm in height. The dry weight of the DEWDECON-2L is 4 kilograms. The device comes complete with a mounting bracket, spare parts, tools, and spare nitrogen cylinders. It is reusable and can be filled, pressurized, and operated while wearing full NBC protective clothing.[1] The NBC-DEWDECON-2L decontamination device is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.21.1. The DEW Engineering and Development Limited NBC-DEWDECON-2L employs semi-aqueous/non-aqueous technology to disseminate DS2 decontaminating agent in a controlled spray to remove chemical agents from contaminated surfaces. Photo reproduced with permission from Jane's Information Group.

6.21.2 NBC-DEWDECON-3L.

The NBC-DEWDECON-3L decontamination device is a lightweight, man-portable system designed to decontaminate exterior equipment. This system is currently in service with Australian, Canadian, and Saudi Arabian armed forces. The NBC DEWDECON-3L employs chemical technology to disseminate DS2 decontaminant in a controlled spray for 1 to 3 meters. This system is used to remove chemical agents from the surface of military equipment and can be filled, charged, and operated while wearing full NBC protective clothing. The device can be pressurized using an air compressor or by hand. The NBC-DEWDECON-3L is deployed on wheeled and track vehicles, aircraft ground support equipment, and exterior bulkheads of ships. This item is supplied with a mounting bracket, pressure gauge, safety relief valve, and operator instructions in English, French, and Arabic. The DEW-3L is corrosion resistant to DS2, reusable, and adaptable to other decontaminants. All required maintenance can be performed by the operator using spare parts and tools provided with each unit. The hand pump on the DEW-3L is interchangeable with the NBC-DEWDECON-20L decontamination device. When stowed in its mounting bracket, the DEW-3L measures 150 mm in width, 160 mm in depth, and 635 mm in height. The dry weight of the NBC-DEWDECON-3L is 5.4 kilograms.[1] The NBC-DEWDECON-3L decontamination device is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.21.3 NBC-DEWDECON-20L.

The NBC-DEWDECON-20L decontamination device, shown in Figure 6.21.3, is a man-portable decontamination system designed to decontaminate exterior equipment. The NBC-DEWDECON-20L employs chemical technology (microemulsion) to disseminate C8-C type decontaminant using a standard 5 gallon (22.7 liter) plastic jerrican. The DEW-20L can be filled, pressurized, and operated wearing full NBC protective clothing. The tank capacity is 18.5 liters and pressurization occurs through an external air source or the use of the integral hand pump. The integral hand pump is interchangeable with the NBC-DEWDECON-3L decontamination device. Any required maintenance can be performed using the spare parts and tool kit provided. Additionally, an optional DS2 conversion is also available that will enable the NBC-DEWDECON-20L to disseminate DS2.

An operator with a fully charged device can decontaminate an M113 armored personnel carrier within 8 minutes. The DEW-20L device is filled using the NBC-DEWDECON-M emulsion mixer and the C8-C decontaminant. The C8-C decontaminant is effective for at least 72 hours.

The NBC-DEWDECON-20L comes equipped with the following items:

- Integral hand pump
- Compressor fill valve
- Pressure gauge
- Safety relief valve
- Quick-disconnect hose
- Two quick-disconnect wand extensions
- Operator/maintenance instructions in English, French, and Arabic.
- Three-piece pole with a scraper
- Scrubing brushes
- Jerrican
- Contents identification ring
- Basic tools

The NBC-DEWDECON-20L is supplied in a rugged fabric bag that fits into any available space on a vehicle. This system measures 600 mm in length, 200 mm in width, and 150 mm in height and weighs 10 kilograms.[1] The NBC-DEWDECON-20L is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

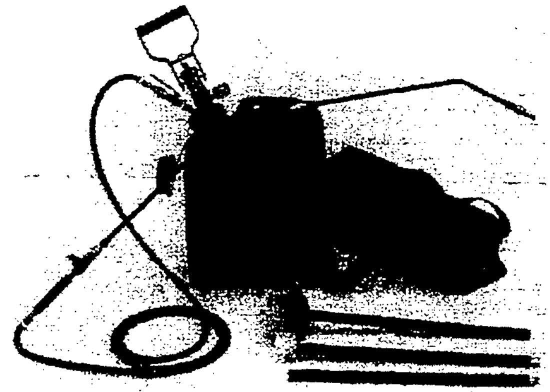


Figure 6.21.3. The DEW Engineering and Development Limited NBC-DEWDECON-20L. Photo reproduced with permission from Jane's Information Group.

6.21.4 NBC-DEWDECON-M Decontaminant Mixer/Applicator.

The NBC-DEWDECON-M mixer/applicator, shown in Figure 6.21.4, is a portable system used to generate calcium hypochlorite based emulsion for decontamination of exterior equipment. This system has been approved for service with the Canadian armed forces. The NBC-DEWDECON-M employs chemical technology (microemulsion) and was developed to provide a non-corrosive and stable means of effectively decontaminating ships, aircraft, vehicles, and equipment.

The C8-C emulsion produced by the mixer neutralizes chemical agents such as TGD, HD, and VX. The emulsion is effective for 24 to72 hours, depending on ambient temperature. A toluene-based perchloroethylene solvent replacement is also available. The mixer can be set up in 10 minutes by two people and will produce a continuous online calcium hypochlorite based emulsion at a rate of up to 2,200 liters per hour. The mixer can be used as a direct applicator or to fill the DEWDECON-20L device for remote decontamination.

The mixer has a built-in rinse capability and a top-mounted accessory box for storing hoses, wands, spare parts, and tools. Both diesel and petrol powered units are available. The overall dimensions of the NBC-DEWDECON-M are 1.3 meters in length, 0.97 meters in width, and 0.89 meters in height. The dry weight is 357 kilograms.[1]

The NBC-DEWDECON-M mixer/applicator is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

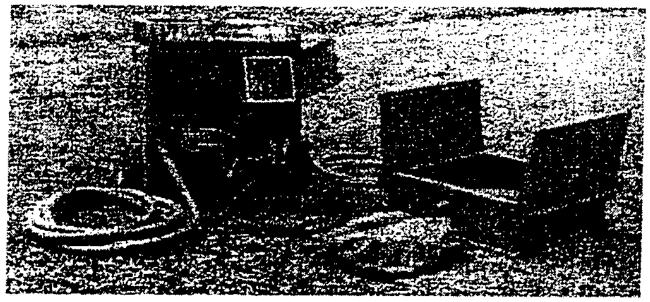


Figure 6.21.4. The NBC-DEWDECON-M mixer/applicator is a portable system used to generate calcium hypochlorite based emulsion for decontamination of exterior equipment. Photo reproduced with permission from Jane's Information Group.

6.21.5 NBC-DEWDECON-PERS Emergency Response Personnel Decontamination Kit.

The NBC-DEWDECON-PERS emergency response personnel decontamination kit, shown in Figure 6.21.5, is a portable system for the decontamination of skin and personal equipment. Depending on decontaminants used in the kit, either chemical or mechanical technologies may be employed. This system contains equipment and supplies for the immediate decontamination of personnel by civilian firefighters, police, and ambulance crews. The kit was designed to be carried in a vehicle cab or cargo area and can be ready for use within seconds. Items necessary for the decontamination of nerve and blister agents are included in this decontamination kit. Illustrated instructions are included with the kit and all components are clearly labeled for quick identification. The kit measures 420 mm in width, 360 mm in depth, and 560 mm in height. The total weight of the kit is 23 kilograms.[1] The NBC-DEWDECON-PERS emergency response personnel decontamination kit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.21.5. The NBC-DEWDECON-PERS emergency response personnel decontamination kit is a portable system for the decontamination of skin and personal equipment. Photo reproduced with permission from Jane's Information Group.

6.22 ENGESA Engenheiros Espacializados SA - BRAZIL.

6.22.1 ENGESA EE-25 NBC Decontamination Truck.

The ENGESA EE-25 NBC decontamination truck, shown in Figure 6.22.1, was designed for the decontamination of personal equipment as well as exterior equipment. This system is manufactured in Brazil by ENGESA Engenheiros Espacializados SA and is believed to be in service in Libya. The ENGESA EE-25, depending on the decontaminant utilized, may employ either chemical or mechanical technologies. The truck disseminates a high-pressure spray of decontaminant solutions to decontaminate troops, roads, and vehicles. This truck uses the 4x4 chassis of the ENGESA EE-25 2,500 kg truck.

The EE-25 truck consists of a 3,000 liter capacity water tank, a 200 liter fuel tank for the heater, and a 160 liter decontaminant solution tank. Additionally, the heater has a fuel consumption rate of 12 liters per hour and the decontaminant solution dispenser has a normal mixing rate of 1 liter decontaminant to every 20 liters of water. The decontaminant solution dispenser increases the flow gradually from 0 to 30 liters per hour. The truck water pump has a flow rate of 48 liters per minute.[1] The ENGESA EE-25 NBC decontamination truck is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

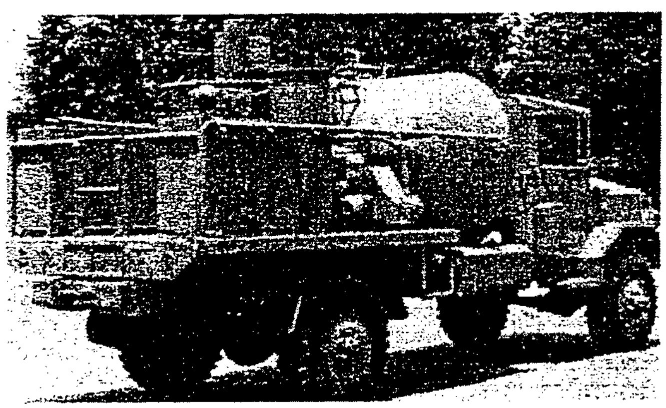


Figure 6.22.1. The ENGESA EE-25 NBC decontamination truck, manufactured in Brazil by ENGESA Engenheiros Espacializados SA. Photo reproduced with permission from Jane's Information Group.

6.23 Engineered Air Systems – UNITED STATES.

6.23.1 M17 Lightweight Decontamination System, Sanator.

The M17 Lightweight Decontamination System, Sanator, shown in Figure 6.23.1, is a lightweight, man-portable, and self-contained decontamination system designed to decontaminate exterior equipment. The system is under license from Karl H. Hoie & Company, Norway, and is in service with Australian, Finnish, Norwegian, Saudi Arabian, Spanish, Swedish, UK, and U.S. armed services. The

SANATOR employs mechanical technology in order to decontaminate surfaces. Approximately 24 liters of superheated water (150 °C) per minute can be dispersed at high-pressures from 1 to 2 spray wands. The system can also supply up to 80 liters of water per minute to 12 showerheads for skin and personal decontamination.

The system is equipped with two high-pressure spray wands, 12 shower points, a 10-m suction hose with filter, two 20-m high-pressure hoses, and a high-volume chemical decontaminant injector (to add decontaminants to the water stream). The system uses a 6,000-liter water tank and is powered by an 8.5 hp two-stroke, air-cooled engine, allowing the system capable of suctioning water from any water source to a height of 3 meters.

The M17 can be operated by one person and in temperatures as low as –40 °C. The basic unit weighs 165 kg and is 1.02 m long, 590 mm wide, and 860 mm high. The M17 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

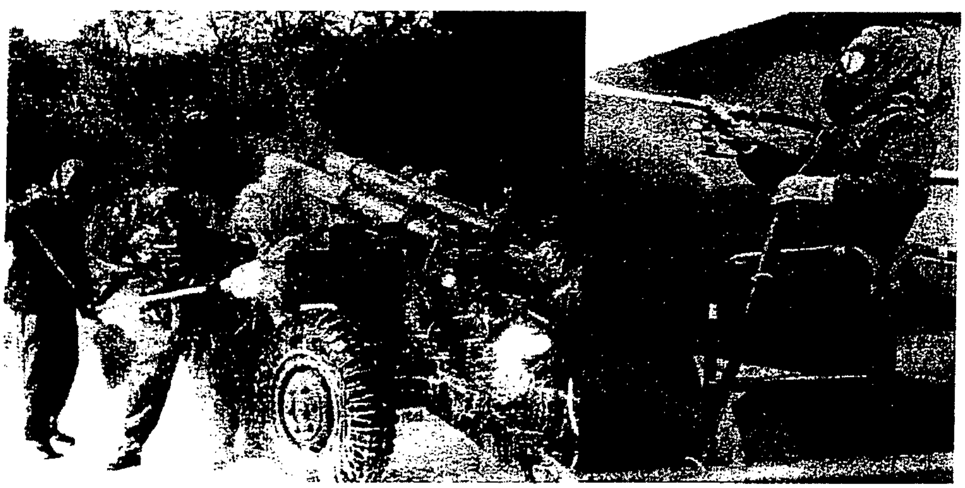


Figure 6.23.1. The LDS NBC-SANATOR III is equipped with two high-pressure spray wands, 12 shower points, a 10-m suction hose with filter, two 20-m high-pressure hoses, and a high-volume chemical decontaminant injector. Photos courtesy of Engineered Air Systems, Inc.

6.24 EST s.r.o. – CZECH REPUBLIC.

6.24.1 <u>OS-3 Decontamination Kit</u>.

The OS-3 decontamination kit, manufactured by EST s.r.o, is a lightweight, man-portable decontamination kit designed for the decontamination of skin and personal equipment and exterior equipment. The OS-3, shown in Figure 6.24.1, is manufactured in the Czech Republic and was used extensively by the Czech Republic forces during operations in the Persian Gulf in 1991. The OS-3 employs high-pressure spray technology. Depending on what decontaminants are used, the kit may employ chemical or mechanical technologies. Two versions of the OS-3 are currently available. These kits differ only in their 12 or 24 volt nominal operating voltage.

The hand-held spray guns may be used to dispense various forms of decontaminant from either pre-packed 1-liter canisters or direct from an open container through a hose up to 3.5 meters long. The power required to operate the OS-3 can be taken from either a vehicle or from batteries carried on a trolley. In use, the decontaminants are sprayed over a contaminated surface from a distance of 100 to 500 millimeters. The contents of a 1 liter prepacked canister can be sprayed in about 90 seconds and 10 canisters can be emptied in 20 minutes. The operating temperature range is from –30 °C to +50 °C.[1] The OS-3 decontamination kit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.24.1. The OS-3 Decontamination Kit, manufactured in the Czech Republic, was used extensively by the Czech Republic forces during operations in the Persian Gulf in 1991. Photo reproduced with permission from Jane's Information Group.

6.25 HazDecon – UNITED STATES.

6.25.1 Mobile Laboratories.

Mobile Laboratories are custom made decontamination laboratories designed to provide decontamination instrumentation, cleanrooms, HEPA filtration, deionized water as well as various other features. The laboratories are commercially available in the U.S. and are manufactured by HazDecon Rental & Sales Inc. They are currently employed by many hazardous waste contractors, laboratories, and several companies and organizations in the U.S. The self-contained systems range in size from 16 to 55 feet in length and 8 to 12 feet in width.

Key features of the mobile laboratories, shown in Figure 6.25.1, include gas chromatograph and atomic absorption vent systems, refrigerators, slide-out gas cylinder racks (2 bottles), a gas/zero air generator hookup, a complete HVAC system, and a wet chemistry area to include sink and drying rack. In addition, these systems include an acid storage cabinet, a flammable storage cabinet, instrument tie-down tracks, a stainless steel gas manifold system, and a fume hood. Additionally, the mobile laboratory comes with 125-amp 240-volt electrical service. Finally, all systems are equipped with 204 inches of curbside countertop space and 238 inches of roadside countertop space. The laboratory has an epoxy floor system, cooler storage, and an optional hot plate, furnace or oven for decontamination crew conveniences. The Mobile Laboratories are intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

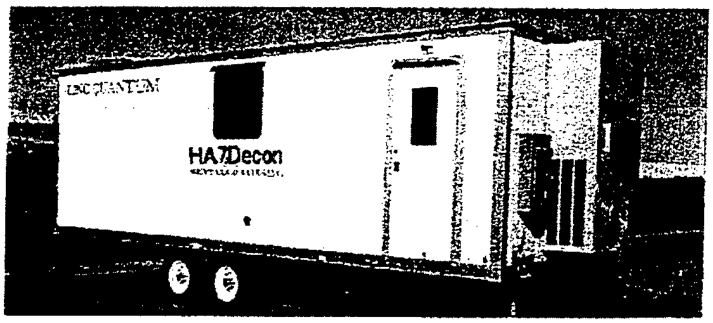


Figure 6.25.1. Haz Decons' Mobile Laboratories are custom made decontamination laboratories designed to provide decontamination instrumentation, cleanrooms, HEPA filtration, deionized water as well as various other features. Photo courtesy of Haz Decon Systems.

6.25.2 Mobile Decon Pad.

The Mobile Decon Pad, shown in Figure 6.25.2, is designed to decontaminate exterior equipment as well as skin and personal equipment. The Decon Pad is commercially available in the U.S. The Mobile Decon Pad can incorporate an already used decontamination spray technology, or one can be designed along with the pad. Depending on the decontamination solutions utilized, the Mobile Decon Pad may employ one or more of the following technologies: chemical, mechanical, high-pressure technologies. The pad is portable and is capable of grossly decontaminating people as well as items ranging in size from small hand tools to large military vehicles.

The system is fully operational in less than two hours. The Mobile Decon Pad has been engineered with a stainless steel structure to resist contaminates and chemical agents. Key features of the system include the ability to maintain an exclusion zone and provide for secondary containment. In addition, the mobile system can be moved from site to site to accommodate new requirements and eliminates the need for fixed facilities. This system is approximately 45 feet in length and 24 feet in width during operations. In transit, the system measures 45 feet in length and 16 feet in width. The Mobile Decon Pad accepts up to 300,000 lbs. of tire and track equipment. The Mobile Decon Pad is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

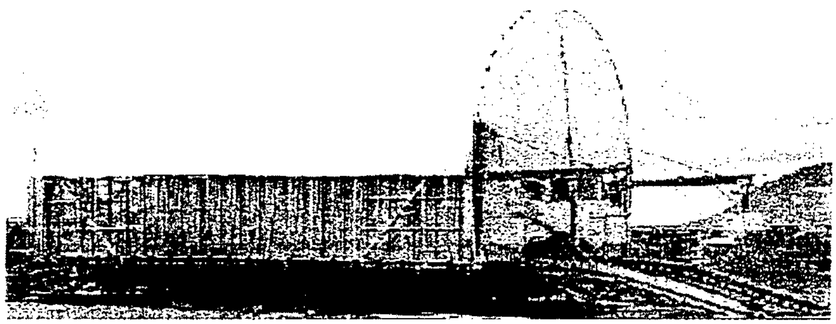


Figure 6.25.1. The Mobile Decon Pad is portable and is capable of grossly decontaminating people as well as items ranging in size from small hand tools to large military vehicles. Photo courtesy of Haz Decon Systems.

6.26 HAZMAT Protective Systems (Pty) Limited – SOUTH AFRICA.

6.26.1 Decontamination Glove.

The Decontamination Glove is an emergency item used to decontaminate skin and personal equipment. The glove is manufactured in South Africa by HAZMAT Protective Systems (Pty) Limited. The glove, shown in Figure 6.26.1 employs sorbent technology and is a double-lined pouch filled with 200 grams of fuller's earth. The glove is dabbed onto the contaminated surface in order to absorb chemical agents. The glove can be fastened around the wrist of a soldier so that immediate decon is possible. The Decontamination Glove is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

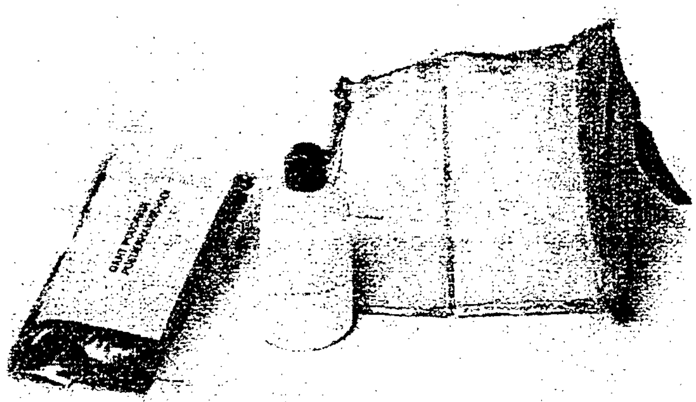


Figure 6.26.1. The by HAZMAT Protective Systems (Pty) Limited Decontamination Glove is an emergency item used to decontaminate skin and personal equipment. Photo reproduced with permission from Jane's Information Group.

6.26.2 Liquid Decontaminant Soap (LDS).

The LDS is an alkaline soft soap used to decontaminate skin and personal equipment. The soap is manufactured in South America by HAZMAT Protective System. The LDS employs chemical technology (nucleophilic substitution). The soap comes in a 25 g plastic tube and is to be used immediately upon contamination. The soap contains compounds that accelerate the hydrolysis of chemical agents. After the soap is applied to the contaminated area, any residue is washed away with large amounts of water. The soap is non-allergenic, non-toxic, and non-irritant.[1] The LDS is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.27 Hughes Safety Showers – UNITED STATES.

6.27.1 Portaflex Decontamination Showers.

The Portaflex Decontamination Showers, shown in Figure 6.27.1, are series of decontamination showers used to wash skin and personal equipment. The Portaflex Decontamination Showers are manufactured in the U.S. by Hughes Safety Showers. The system primarily employs mechanical technology. The series is comprised of four different showers, the Portaflex 75, 200, 300, and 500. The showers vary only in size and weight.

The Portaflex 75 is the smallest of the shower series. It weighs 17 kg and is 104 cm long, 76 cm wide, and 16 cm high. The shower unit is a compact unit and is only to be used until a major, full-size unit is available. The Portaflex 75 is made of a heavy-duty stainless steel pipe work base. It is equipped with a 1.5 inch Durlaine flexible hose with six spray nozzles that disperses water on all sides of the contaminated individual. The Portaflex 75 can be set up in 30 seconds.

The Portaflex 200 is a full size decontamination shower weighing 29.5 kg and is 128 cm long, 52 cm, wide, and 17 cm high. The shower base is made from stainless steel pipe work and can also be set up in 30 seconds.

The Portaflex 300 is also a full size decontamination shower. It weighs 25 kg and is 77 cm long, 50 cm wide, and 19 cm high. The shower is made up of four 0.5 inch (38 mm) lay-flat Duraline hoses, that form four shower legs. Each leg is fitted with four spray nozzles. When under pressure, the hose legs and the base frame assembly become rigid, thus forming a stable frame for the decontamination of personnel. The system can be assembled in 45 seconds and can be easily transported in a carrying case that doubles as the base platform of the shower unit.

The Portaflex 500 is a multi personnel decontamination shower module. It weighs 85 kg and is 140 cm long, 40 cm wide, and 49 cm high. The system is designed to provide the decontamination of mass casualties. The Portaflex 500 is comprised of 5 separate shower modules that are inter-connected. The system can also come equipped with screens for privacy. The entire system can be assembled in less than 5 minutes. The Portaflex Decontamination Showers are intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

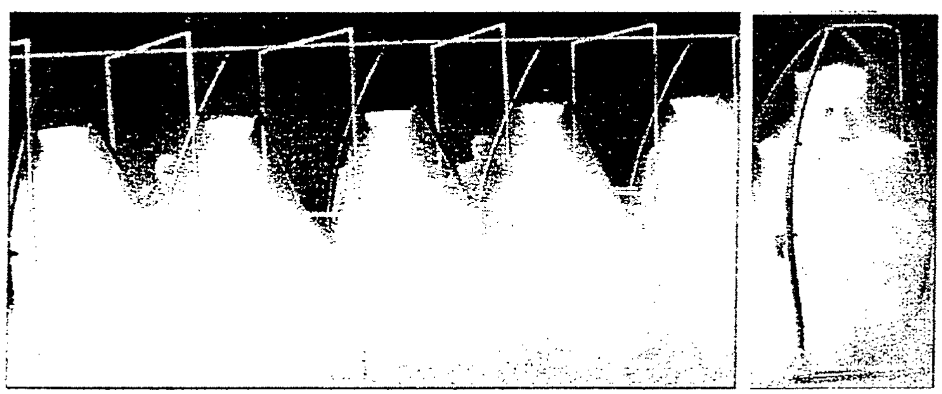


Figure 6.27.1. The Portaflex Decontamination Showers, manufactured by Hughes Safety Showers, are series of decontamination showers used to wash skin and personal equipment. Photos courtesy of Hughes Safety Showers.

6.27.2 Portaflex CUPOLA Decontamination Shelter.

The Portaflex Cupola, shown in Figure 6.27.2, is a decontamination shelter used with the Portaflex 300. The Cupola is designed to provide containment of contaminated water or decontamination solutions following a decontamination effort. The Cupola allows contaminated personnel to walk through from the dirty area to a clean area while undergoing decontamination using the Portaflex 300.

The shelter frame incorporates four legs that are inflated under low pressure. An inner lining that has windows on two opposite sides to enable the decontamination process to be observed, runs across the legs. The openings are fitted with drop down splash flaps to eliminate overspray. The Portaflex Cupola weighs 45 kg and is 120 cm long, 60 cm wide, and 50 cm high. The system can be assembled in 45 seconds and can be easily transported. The Portaflex Cupola is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.27.2. The Portaflex Cupola is a decontamination shelter used with the Portaflex 300 to provide containment of contaminated water or decontamination solutions following a decontamination effort. Photo courtesy of Hughes Safety Showers.

6.27.3 <u>Response Decontamination Unit</u>.

The Response and Decontamination Unit is a multi purpose unit that is used to decontaminate skin and personal equipment that have become contaminated with chemical agents. The unit is commercially available in the U.S. The unit employs chemical (primary) and mechanical (secondary) technologies. The unit, shown in Figure 6.26.3, consists of a six-meter long trailer that is equipped with a water heater and two showers for individuals. The shower area is large enough to accommodate walking personnel victims on stretchers. The trailer is equipped with a 240 volt, 2.2 KVA Honda generator. The Response and Decontamination Unit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

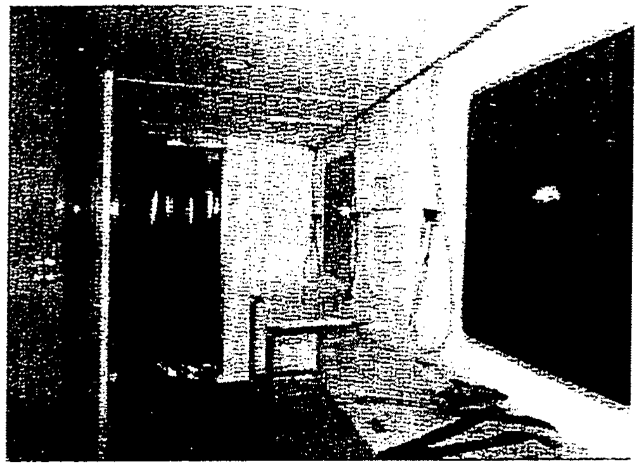


Figure 6.27.3. The Response and Decontamination Unit consists of a six-meter long trailer that is equipped with a water heater and two showers for individuals.

6.28 J. Blaschke Wehrtechnik GmbH - AUSTRIA.

6.28.1 Expendable Foil Decontamination Collecting Trough.

The Expendable Foil Decontamination Collecting Trough, manufactured in Austria by J Blaschke Wehrtechnik, is a low-transport volume and weight decontamination solution collecting trough system designed to collect residues after spraying contaminated equipment with decontaminants. The troughs are in service by the Austrian armed forces.

The troughs, shown in Figure 6.28.1, vary in size from 2 x 3 meters to 20 x 30 meters. They are large enough to accommodate planes and tanks. The vehicle is driven up on to the trough and then sprayed down. The residue solutions are then collected in the trough and then drawn off using a diaphragm self-priming pump, which is provided. The foil used to make the troughs can be reused disposed of without hazard. All parts used in the containment system are resistant to CB agents and other chemical reactions. The Expendable Foil Decontamination Collecting Trough is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

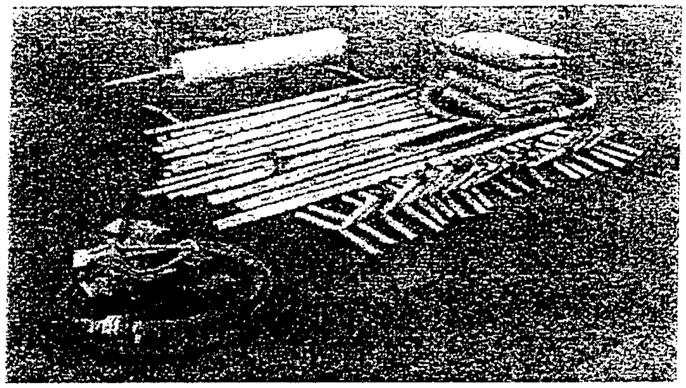


Figure 6.28.1. The Expendable Foil Decontamination Collecting Trough, manufactured in Austria by J Blaschke Wehrtechnik are in service by the Austrian armed forces. Photo reproduced with permission from Jane's Information Group.

6.29 Jugoimport-SDPR - YUGOSLAVIA.

6.29.1 Personal Decontamination Kit LPD-M3.

The LPD-M3, shown in Figure 6.29.1, is a personal decontamination kit used to decontaminate skin and personal equipment. The kit is manufactured in Yugoslavia by Yugoimport SDA and is in service with the Yugoslav Army. The kit employs sorbent technology. The kit is based around a textile glove, which consists of two pads containing fuller's earth. One pad is used for skin decontamination, while the other is a soft fabric pad for cleaning decontaminated surfaces. The kit is issued in a wrapped sealed pouch. The LPD-M3 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

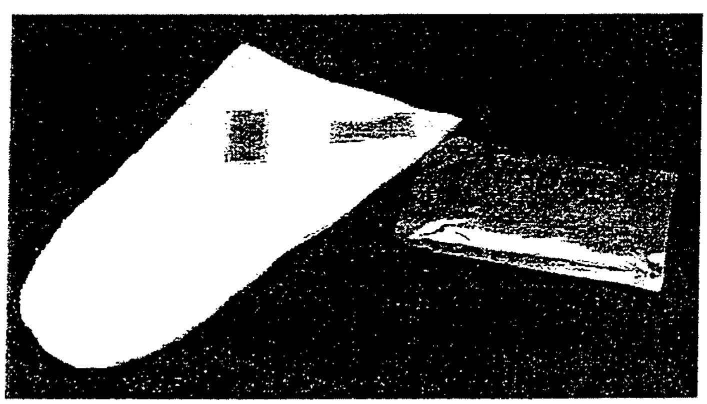


Figure 6.29.1. The LPD-M3, manufactured in Yugoslavia by Yugoimport SDA, is a personal decontamination kit used to decontaminate skin and personal equipment. Photo reproduced with permission from Jane's Information Group.

6.30 Karl H. Hoie & Co A/S - NORWAY.

6.30.1 LDS NBC-SANATOR III Lightweight Decontamination System.

The LDS NBC-SANATOR III, shown in Figure 6.30.1, is a lightweight, man-portable, and self-contained decontamination system designed to decontaminate exterior equipment. The system is manufactured in Norway by Karl H. Hoie & Company and is in service with Australian, Finnish, Norwegian, Saudi Arabian, Spanish, Swedish, UK, and U.S. armed services. The SANATOR employs mechanical technology in order to decontaminate surfaces. Approximately 24 liters of superheated water (150 °C) per minute can be dispersed at high-pressures from 1 to 2 spray wands. The system can also supply up to 80 liters of water per minute to 12 showerheads for skin and personal decontamination.

The system is equipped with two high-pressure spray wands, 12 shower points, a 10-m suction hose with filter, two 20-m high-pressure hoses, and a high-volume chemical decontaminant injector (to add decontaminants to the water stream). The system uses a 6,000-liter water tank and is powered by an 8.5 hp two-stroke, air-cooled engine allowing the system capable of suctioning water from any water source to a height of 3 meters.

The SANATOR can be operated by one person and in temperatures as low as –40 °C. The basic unit weighs 165 kg and is 1.02 m long, 590 mm wide, and 860 mm high. The U.S. Army currently fields the SANATOR as the M17 Lightweight Decontamination System, Sanator.[1] The SANATOR is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

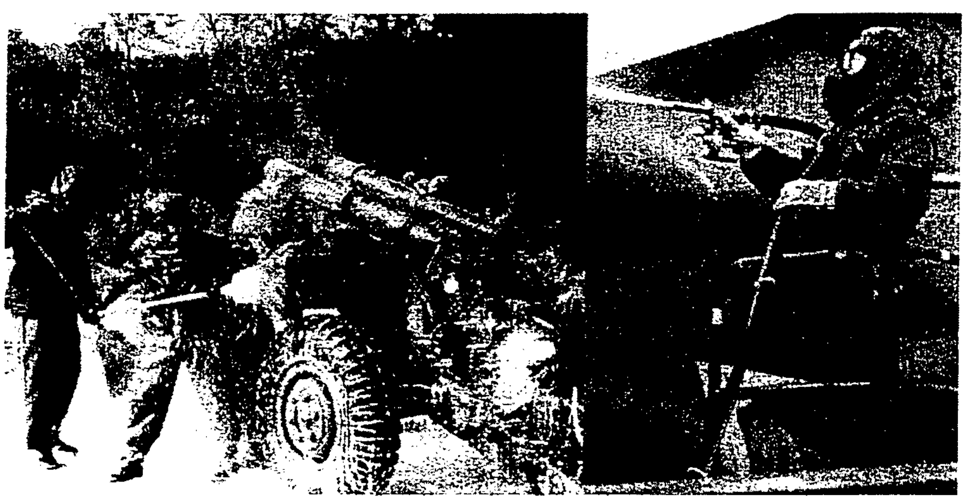


Figure 6.30.1. The LDS NBC-SANATOR III is equipped with two high-pressure spray wands, 12 shower points, a 10-m suction hose with filter, two 20-m high-pressure hoses, and a high-volume chemical decontaminant injector. Photos courtesy of Engineered Air Systems, Inc.

6.31 Kintex - BULGARIA.

6.31.1 DK-5 Vehicle Decontamination Kit.

The DK-5 is a decontamination kit used to decontaminate exterior equipment (i.e. vehicles). The kit is currently in production and is marketed by Kintex in Bulgaria. The decontamination kit employs low-temperature thermal technology coupled with chemical or mechanical technologies (depending on the decontaminant solution used). The DK-5, shown in Figure 6.30.1, utilizes pressure taken from the vehicle's exhaust system and various decontamination solutions in order to decontaminate carrier vehicles. To decontaminate a large ZIL-130 truck, the kit requires about 50 and 60 liters of decontaminating solution while the amount necessary to decontaminate a smaller vehicle is between 30 and 40 liters. The kit weighs 14 kg and is equipped with a 40-liter rubber tank, a plastic container for the decontaminating agent, wash nozzle, and scrubbing kit. The decontaminating agent needed to treat 1 m^2 is between 1 and 1.5 liters.[1] The DK-5 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

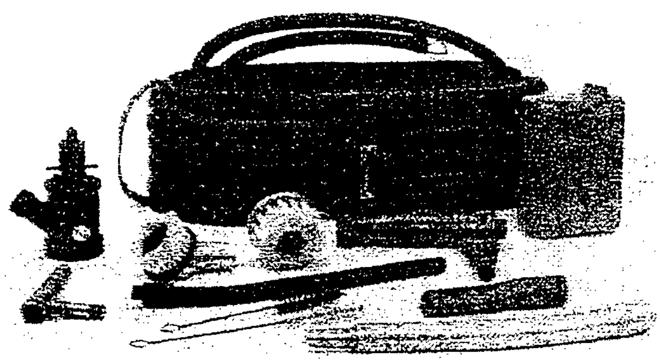


Figure 6.31.1. The DK-5, offered by Kintex of Bulgaria uses pressure taken from the vehicle's exhaust system and various decontamination solutions to decontaminate vehicles. Photo reproduced with permission from Jane's Information Group.

6.31.2 DKV-M Decontamination System.

The DKV-M is a decontamination system designed to decontaminate exterior equipment. The system, shown in Figure 6.30.2, utilizes a high-pressure spray (6.5 Pa) of a decontamination solution (calcium-hypochlorite solution or a multi-agent solution) to treat contaminated surfaces. The system, depending on which decontamination solution is used, may employ either chemical or mechanical technologies. The system holds 22 liters of decontaminant solution, uses an 8-m hose and brush system for dispersion, and is capable of decontaminating up to 100 m^2 of area.[1] The DKV-M is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.31.2. The DKV-M uses a high-pressure spray (6.5 Pa) of a decontamination solution (calcium-hypochlorite solution or a multi-agent solution) to treat contaminated surfaces. Photo reproduced with permission from Jane's Information Group.

6.31.3 KID-6 and KID-12 Individual Decontamination Kits.

The KID-6 and the KID-12 are two individual decontamination kits designed to decontaminate personal equipment. The kits are comprised of individual units each equipped with a decontaminant dispenser weighing 220 g and a 90 g supply of decontaminant (Fuller's Earth). The KID-6 holds six individual units, while the KID-12 contains twelve. The decontaminant dispenser employs sorbent technology and is capable of decontaminating a rifle in 1 minute and personal clothing in 10 to 15 minutes. The KID-6 weighs 4.5 kg and the KID-12 weighs 7.5 kg. Both kits are supplied in metal containers.[1] The KID-6 and the KID-12, shown in Figure 6.30.3, are intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

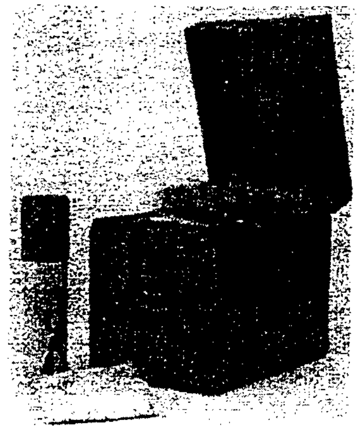


Figure 6.31.3. The KID-6 and the KID-12 are comprised of individual units each equipped with a decontaminant dispenser weighing 220 g and a 90 g supply of decontaminant (Betonite). Photo reproduced with permission from Jane's Information Group.

6.31.4 KBSO Vehicle-Mounted Decontamination Kit.

The KBSO vehicle-mounted decontamination kit, shown in Figure 6.30.4, is designed for the decontamination of personal equipment. The KBSO, employing mechanical technology, is equipped with a pressurized aerosol spray canister, a toolkit, and a plastic container that holds 5 liters of decontaminating solution. The kit comes in two sizes. The smaller version of the KBSO does not come with the plastic container. The small kit weighs 19-kg is able to decontaminate 20 m^2 of area, while the larger kit weighs 25 kg and can decontaminate up to 40 m^2.[1] The KBSO Vehicle-Mounted Decontamination Kit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

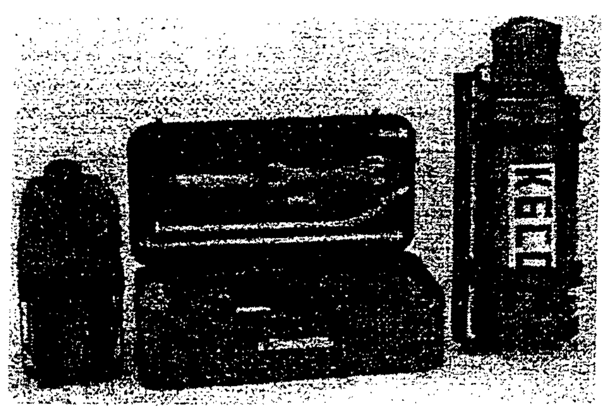


Figure 6.31.4. Kintex's KBSO vehicle-mounted decontamination kit. Photo reproduced with permission from Jane's Information Group.

6.32 Kraneks Engineering Company - RUSSIAN FEDERATION AND ASSOCIATED STATES.

6.32.1 Decontamination Apparatus, Truck-Mounted, Model ARS-14K.

The Model ARS-14K is a truck-mounted apparatus designed to decontaminate exterior equipment as well as large areas (i.e. terrain). The ARS-14K is manufactured in the Russian Federation and Associated States. The apparatus disseminates decontamination solutions at high pressure. Depending on which decontamination solutions are used, the system may employ either mechanical or chemical technologies. The ARS-14K is equipped with a 2,700 liter tank, a 1,040 liter tank, two mechanical pumps, a hand pump, pipelines, an intake for chemicals, ten 20 liter canisters, and dispensers.

The apparatus, shown in Figure 6.31.1, provides the capability to set up 5 to 6 decontamination stations at one time. Approximately 6 to 8 large pieces of equipment can be decontaminated each hour as well as a 5-m strip of land over a length of 1,400 m. The ARS-14K can be set up in 8 to 5 minutes and can be operated in temperatures ranging from -40 to 50 °C.[1] The Model ARS-14K is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

Figure 6.32.1. The Model ARS-14K is a truck-mounted apparatus with the capability to set up 5 to 6 decontamination stations at one time. Photo reproduced with permission from Jane's Information Group.

6.33 Minimax, GmbH – GERMANY.

6.33.1 NBC Decontamination Truck.

The NBC Decontamination Truck, shown in Figure 6.33.1, is used to decontaminate exterior equipment as well as large areas (i.e. terrain). The truck is manufactured in Germany by Minimax GmbH and is in service with the German armed forces. The truck is used to carry a variety of equipment for decontamination. Depending on which decontaminants are utilized, the NBC Decontamination Truck may employ either mechanical or chemical technologies. The truck is equipped with a water heater, a dry mixer for decontaminants, spray bars, a pump to suction water from reservoirs, and hoses. The water heater has a flow capacity of 600 to 3,600 liters per hour and the spray bars dispense water/ decontaminants at a flow rate of 465 liters/min and has a range of 8 m. The truck is capable of covering contaminated areas at a rate of 1.16 liters/hour. The truck is 8.62 m long, 2.5 m wide, and 3.48 m high and weighs 18,700 kg.[1] The NBC Decontamination Truck is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

Figure 6.33.1. The NBC Decontamination Truck, manufactured in Germany by Minimax GmbH, is used to carry a variety of equipment for decontamination including a water heater, a dry mixer for decontaminants, spray bars, a pump to suction water from reservoirs, and hoses. Photo reproduced with permission from Jane's Information Group.

6.34 MITI Manufacturing Inc. – UNITED STATES.

6.34.1 <u>DeCon Hoop</u>.

The DeCon Hoop, shown in Figure 6.34.1, is a portable decon spray hoop used to decontaminate skin and personal equipment as well as exterior equipment. The DeCon Hoop is commercially available in the U.S. and is manufactured by MITI Manufacturing. The apparatus employs mechanical technology. The apparatus disseminates water and/or other decontaminants at high-pressures. The shower is made from durable, lightweight, corrosion free aluminum pipe and tubes. The DeCon Hoop is shaped in an octagon with an extendable handle. The hoop is passed over a contaminated individual or equipment as water is sprayed out of eight nozzles, one nozzle on each side of hoop. The hoop sprays 4.6 GPM of water or a substituted decontaminant. The hoop has an outside diameter of 45 inches, inner diameter of 39 inches, and it weighs 10 pounds. The Decon Hoop is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

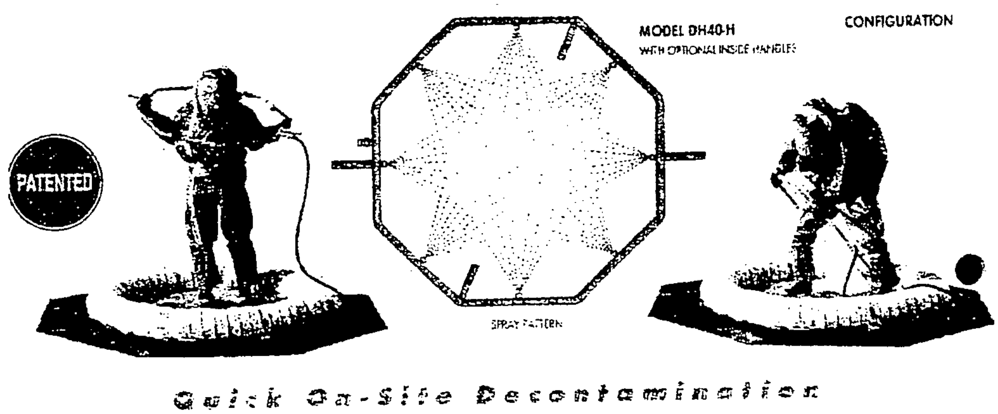


Figure 6.34.1. The DeCon Hoop, manufactured by MITI Manufacturing, disseminates water and/or other decontaminants at high-pressures. Photo courtesy of MITI Manufacturing.

6.35 NBCD Systems – FRANCE.

6.35.1 <u>NBCD Systems Personal Decontamination Kit</u>.

The NBCD Systems Personal Decontamination Kit is a lightweight, man-portable, self-contained decontamination kit used to decontaminate skin and personal equipment. This system is manufactured in France by NBCD Systems. The kit employs both sorbent and chemical technology. The kit is designed to be effective against most mustard, nerve, and other chemical agents. The kit is equipped with a pre-impregnated towel in a sealed package, a vial of decontaminating liquid, and an absorbent glove that can be tightened at the wrist. The absorbent glove is used first in order to remove the majority of agent contamination on personal equipment. The towel and the decontaminating liquid are then used to neutralize any remaining agent. The contents of the kit are issued packed in either a flat box or in a cylindrical case. The flat case is 230 mm long, 130 mm in wide, and 35 mm in high. The cylindrical case is 60 mm in diameter and 210 mm in length. Both kits weigh 210 grams and have a storage life of five years.[2] The NBCD Systems Personal Decontamination Kit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.36 Ocher Engineering Plant - RUSSIAN FEDERATION AND ASSOCIATED STATES.

6.36.1 Decontamination Apparatus, Truck Mounted, Models ARS-15 and ARS-15M.

The Decontamination Apparatus, Truck Mounted, Model ARS-15 and ARS-15M, shown in Figure 6.36.1, are mobile decontamination systems used to decontaminate exterior equipment and large areas. The systems are manufactured in the Russian Federation and Associated States Ocher Engineering Plant and are currently in service in those states. Both systems employ a combination of low-temperature thermal technology with mechanical technology to disseminate water at high-pressure. The ARS-15 is similar in design to the ARS-14, but is mounted on the chassis of the Ural-375 (6x6) 4,000-kilogram truck. The improvements made to the ARS-15 include the ability to operate in humid environments and continued operation at temperatures as low as –15 degrees °C. The operating range for the ARS-15 system ranges from –40 to +50 °C.

This system is used to decontaminate weapons, vehicles, equipment, and terrain. The ARS-15 can effectively decontaminate up to 12 vehicles every hour and between 23 to 50 vehicles (depending on size) per tank filling. Three crewmembers are required to operate the ARS-15 and approximately 15 minutes are required to make the system operational.

The Model ARS-15 is equipped with a 2,300-liter tank, a TsN-245 mechanical pump made from titanium, and a heater capable of heating the tank contents in 1 hour to 70 degrees °C. The ARS-15 is capable of decontaminating 12 vehicles per hour and can supply enough warm water to shower units to allow 24 people to bathe each hour.

The latest version of this equipment is the ARS-15M, however there are few design changes from the earlier version.[1] The Decontamination Apparatus, Truck Mounted, Model ARS-15 and ARS-15M are intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

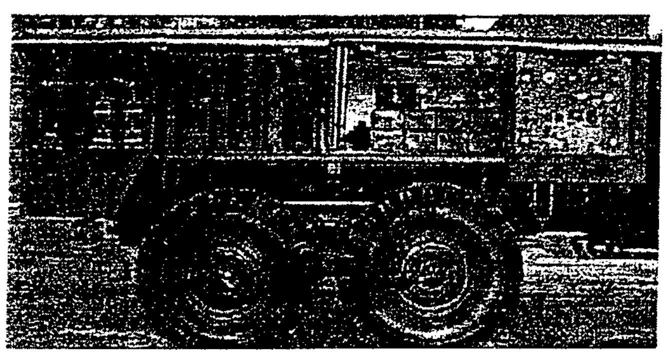


Figure 6.36.1. The Decontamination Apparatus, Truck Mounted, Model ARS-15 and ARS-15M manufactured in the Russian Federation and Associated States Ocher Engineering Plant. Photo reproduced with permission from Jane's Information Group.

6.37 O'Dell Engineering Limited - CANADA

6.37.1 Reactive Skin Decontaminant Lotion - RSDL

The RSDL is skin decontamination lotion designed to neutralize chemical agents on skin and personal equipment. The lotion is manufactured in Canada by O'Dell Engineering Limited and is in service with the Canadian Armed Forces. The lotion employs chemical technology and is effective on vesicants (H and L) and nerve agents (G and V).

The lotion, shown in Figure 6.37.1, is supplied in individual pouches with a foam applicator for personal decontamination and equipment decontamination. The lotion can also be distributed in large containers in order to treat mass casualties. The lotion is non-toxic and has been proven to be safe to use on the eyes. Any left over residue can be washed away with water.[1] The RSDL is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area	

Figure 6.37.1. The RSDL employs oxidation technology in order to decontaminate skin and personal equipment. Photo reproduced with permission from Jane's Information Group.

6.38 Odenwald-Werke Rittersbach GmbH (OWR) - GERMANY.

6.38.1 OWR DEKON Decontamination System.

The OWR DEKON Decontamination System is a mobile decontamination system used to decontaminate exterior equipment along with skin and personal equipment. This system is manufactured in Germany by Odenwald-Werke Ritterbach GmbH (OWR) and is currently in production. Depending on which decontamination solutions are utilized, the DEKON system employs either mechanical or chemical technologies. The DEKON decontamination system is comprised of the following five components: the DETECT 1000, the DEKON 2000, the SHOWER 3000, the WASH 4000, and the MOBILE WORKSHOP 5000.

The DETECT 1000 is the first component of the system. It is normally carried on an 8 x 8 chassis and contains three primary compartments. The first compartment is a laboratory with an air-conditioned filtered overpressure system. Instruments for detecting, measuring, and marking NBC contaminated areas are maintained in this area. The laboratory is also equipped with communications equipment to allow all findings to be easily reported. The second compartment is an accessible decontamination lock. This area includes a shower basin with an operable showerhead. This area is also utilized as a reception station for contaminated clothing and equipment. Finally, the third compartment is the decontamination center. This is where all necessary equipment is stored. Also, this compartment houses a 600 liter tank, the hot water plant, and storage for decontaminants as well as any associated accessories. The wide area distribution of decontaminants is accomplished with a spreader and spray bar fitted at the rear of the vehicle. Horns, lamps, and other warning devices can also be fitted to the system.

The DEKON 2000 is the second component of the system and can be operated independently of the rest of the system. It is a decontamination disaster protection vehicle. The DEKON 2000 was designed to be used for personnel and equipment decontamination, area decontamination, and for the production of toxic-free drinking water. Equipment and devices used with the DEKON 2000 are carried on a flat working area and are covered with a canvas tilt. Equipment on the DEKON 2000 includes wide jet spray tubes, mixing injectors for liquid, powder decontaminants, a water purifying plant, a water circulation heater, an electrical control panel, and 380/220 V and 24 V generators.

The third component of the system is the SHOWER 3000. This unit is capable of supplying cleansing showers for up to 3,500 people in a 24-hour period. The SHOWER 3000 is equipped with a water circulation heater, an electrical generator, decontaminating agents, and various other devices and accessories.

The WASH 4000 is a field laundry system capable of processing 100 to 150 kilograms of clothing each hour. This unit includes two washing machines, a rotary dryer, a 3,500 liter water tank, and various other devices and accessories.

Finally, the last component of the DEKON Decontamination System is the MOBILE WORKSHOP 5000. This unit is a van that contains a workshop and a supply of spare equipment. It is capable of maintaining the entire DEKON Decontamination System in the field.

A Decontamination Emulsion Direct Application System (DEDAS) can be fitted on all vehicles in the DEKON system. This allows for an output of over 1000 liters/minute of decontamination solution.[2] The DEKON Decontamination System is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.38.2 DEKON Trailer 6000.

The OWR DEKON Trailer 6000, shown in Figure 6.38.2, is a multi-purpose decontamination system used to decontaminate skin and personal equipment, fixed sites, and exterior equipment. The DEKON Trailer 6000 employs mechanical technology. In addition to decontaminating personnel and equipment this system can also be used for extinguishing fires and providing field showers.

This system is equipped with a 1,000-liter water tank, several 1,000-liter collapsible water tanks, and water heater unit, which has the capability of heating 3,600 liters of water to a temperature of 28°C per hour. The power necessary to pump the water for showers is provided through an engine located on the trailer. The single-axle trailer can be towed by any vehicle with a 3,000 kilogram and above towing capacity. A canvas frame cover is used to enclose the trailer during transportation. This canvas can also be used as a dressing station for protection from the weather while taking showers.

The DEKON Trailer 6000 is also equipped with equipment necessary for mixing decontaminants with water and is capable of producing foam for fighting fires and decontamination operations. Additional space on the trailer is used to transport entrenching tools, spare parts, first aid kits, fire extinguishers, and extra supplies of decontaminant solutions.[1] The DEKON Trailer 6000 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

Figure 6.38.2. The OWR DEKON Trailer 6000 can also be used for extinguishing fires and providing field showers. Photo reproduced with permission from Jane's Information Group.

6.38.3 OWR DECOFOG III Decontamination System and GD Solution.

The DECOFOG III is a man-portable decontamination system used to decontaminate exterior equipment. This system employs chemical technology and emits NBC decontamination agents in the form of a fine aerosol cloud that resembles a natural fog. This device disseminates the decontaminant GD5.

The dispenser on this system, shown in Figure 6.38.3, uses a 24-hp pulse jet engine capable of producing a flow rate of 10 to 25 liters/hour. The flow rate is dependent upon the particular nozzle being used with the system. The DECOFOG III is equipped with a 5-liter transparent decontaminant tank. The decontaminant fog is created using a 0.3-liter combustion chamber. Four 1.5-volt dry batteries power the quick-start electronic ignition system. This allows for an average fuel consumption of between 1.5 and 1.9 liters/hour given a tank capacity of 2 liters.

The decontaminant is applied to the contaminated surface in the form of small droplets. These droplets are approximately 4 micrometers in diameter. The droplets are dispensed in a thin fog-like form that allows the decontaminant to flow and clean areas that are usually hard to reach. The DECOFOG III weighs 7 kg (empty) and is 106 cm long, 29 cm width, and 33 cm high.[1]

The DECOFOG III is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

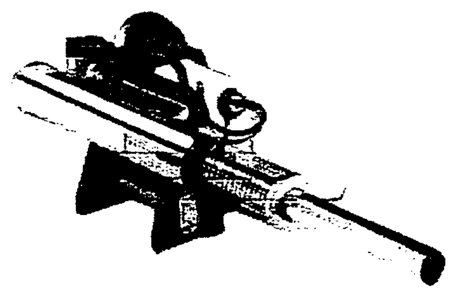


Figure 6.38.3. The DECOFOG III is a man-portable decontamination emits NBC decontamination solutions in the form of a fine aerosol cloud that resembles a natural fog. Photo courtesy of Odenwald-Werke Ritterbach GmbH (OWR).

6.38.4 <u>OWR Clean 6000 G and DECO-Clean 7000 G Decontamination Units</u>.

The Clean 6000 G and the DECO-Clean 7000 G are portable decontamination systems used to decontaminate exterior equipment. These systems, shown in Figure 6.38.4, are manufactured in Germany by Odenwald-Werke Rittersbach GmbH (OWR) and are currently in production. The Clean 6000 G and the DECO-Clean 7000 G decontamination systems employ both mechanical technology and chemical technology. The systems utilize GD 5, which provides the decontamination capability. Both systems are sled-mounted, underneath which are small wheels that allow for easy transport. The DECO-CLEAN 7000 G is equipped with a decontamination module with a pump and two spray lances that are used to disperse decontaminants (i.e. GD5) onto contaminated surfaces. The 7000 G weighs 426 kg and is 66 inches long, 37.5 inches wide, and 40.3 inches long. The 6000 G is smaller in weight than the 7000 G and is equipped with the two spray lances, and twin continuous-flow boilers. The 6000 G weighs 416 kg and is 66 inches long, 37.5 inches wide, and 40.3 inches high.[1] The Clean 6000 G and the DECO-Clean 7000 G is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

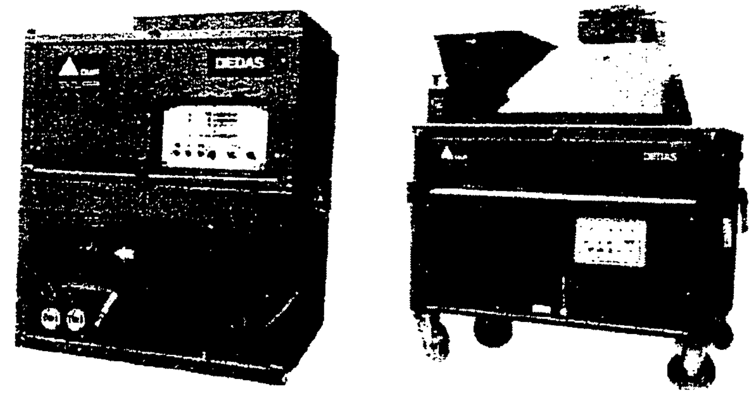
Figure 6.38.4. The Clean 6000 G and the DECO-Clean 7000 G are portable decontamination systems manufactured in Germany by Odenwald-Werke Rittersbach GmbH (OWR). Photo reproduced with permission from Jane's Information Group.

6.38.5 OWR DEDAS Decontamination Unit.

The Decontamination Emulsion Direct Application System (DEDAS), shown in Figure 6.38.5, is a portable decontaminant system used for producing decontaminant solutions in the field. Depending on the decontaminant used, the DEDAS employ either mechanical or chemical technologies. This system can be used in conjunction with existing decontamination systems or be used separately as a central unit for future decontamination systems. The unit is ruggedly constructed, corrosion resistant, and can be operated as either a ground-mounted unit or a vehicle-mounted unit. The DEDAS is equipped with a malfunction indicator, a flow and level controller, and an automatic switch-off sequence. The system is constantly mixing liquid and solid decontaminants automatically. The DEDAS is manufactured in two models, the DEDAS 35 and the DEDAS 100.

The DEDAS 35 weighs 100 kg and is 70 cm long, 50 cm wide, and 85 cm high. The DEDAS 35 produces an emulsion rate of 35 liters per minute and a decontamination solution flow rate for terrain decontamination of 70 liters per minute. The DEDAS 100 weighs approximately 200 kilograms and is 1,100 mm long, 650 mm wide, and 710 mm wide. The DEDAS 100 operates at a pressure of 3.5 bars and is capable of producing 100 liters per minute of decontamination emulsion and 200 liters per minute of diluted solutions for terrain decontamination.[1] The DEDAS is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	



DEDAS 35 **DEDAS 100**

Figure 6.38.5. The Decontamination Emulsion Direct Application System (DEDAS) is a portable decontaminant system used for producing decontaminant solutions in the field. Photo courtesy of Odenwald-Werke Rittersbach GMBH.

6.38.6 OWR Containerized Multi-Purpose Decontamination System-MPD12 and PD12.

The OWR Containerized Multi-Purpose Decontamination System MPD12 and PD12 are mobile decontamination systems used for the decontamination of exterior equipment as well as for the decontamination of skin and personal equipment. Both the MPD12 and PD12 employ mechanical technology. The MPD12 system, shown in Figure 6.38.6, was designed to decontaminate personnel, equipment, weapons, vehicles, aircraft, helicopters, and terrain. This system is transported by vehicle as a containerized unit and can also be transported by helicopter.

The MPD12 incorporates a steam jet cleaner for decontaminating equipment. The unit used with the MPD12 is the PD12, which is used for the decontamination of personnel, their personal clothing, and equipment. In operation, this unit incorporates a pre-decontamination station with two 10-liter/minute shower units that are equipped to handle the addition of decontamination solution. Personnel are signaled to enter the shower area of the system by either audio or visual signal. The shower area is equipped with 12 shower units, each dispersing 5 liters/minute. However, each of the 12 shower units can be supplied with varying amounts of decontaminants and water.

The PD12 is equipped with a 1,400-liter aluminum water tank. There are three additional 1,000-liter flexible tanks that are also maintained for backup operations. If required, the PD12 water pump can supply up to 30,000 liters/hour from a water source located 15 meters below the surface.[1] The MPD12 and PD12 are intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.38.6. The MPD12 system was designed to decontaminate personnel, equipment, weapons, vehicles, aircraft, helicopters and terrain. Photo courtesy of Odenwald-Werke Ritterbach GmbH (OWR).

6.38.7 <u>OWR Dress DEKONT 8000.</u>

The Dress DEKONT 8000 is a mobile and drying unit used for the decontamination personal equipment. The system, manufactured in Germany by Odenwald-Werke Rittersbach GmbH (OWR) employs both low-temperature thermal and chemical technology. The system disinfects and dries NBC protection suits in one hour using hot air at a temperature varying from 50 to 160 °C. The suits are hung on special hangers equipped with spacers and spray systems to ensure distribution of air and decontaminant solutions around the interior of the garments. In addition, spray jets are installed in the upper corners of the disinfecting and drying chamber in order to spray the clothing exteriors. The Dress DEKON 8000 is equipped with an air circulation unit to ensure air is circulated several times every minute. Approximately 10 per cent of the circulated air is directed outside the system and replaced by fresh air.[1] The Dress DEKON 8000 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.39 Pentek – UNITED STATES.

6.39.1 <u>Corner-Cutter®</u>.

The Corner-Cutter® is a dustless surface decontamination system used to safely remove lead-based paints, chemical spills, epoxy coatings, radioactivity, and other hazardous contaminants from both steel and concrete surfaces. The Corner-Cutter®, shown in Figure 6.39.1, is available commercially in the U.S. and is manufactured by Pentek, Incorporated. The system is similar to a vacuum cleaner and employs mechanical technology to clean a variety of surfaces. It is designed to allow the shroud to conform to all types of corners (i.e. sharp, inside, outside) and flat surfaces. The Corner-Cutter® can clean 20-30 square feet of flat surface per hour or 30-60 linear feet of edges and corners per hour. The unit consumes 5 standard cubic feet per minute of air at 90 psig and requires a ½ inch diameter air hose.

The cutting needles consist of 3 millimeter diameter steel needles for concrete or steel and 2 millimeter diameter needles for steel surface preparation. The Corner-Cutter® is 14 inches in length, has a cutting width of 1.75 inches, and weighs approximately 9 pounds.

The Corner-Cutter® is a vacuum containment system that requires a minimum of 50 standard cubic feet per minute vacuum source at the 1.5-inch diameter vacuum hose connection. This unit interfaces directly with the Pentek-designed VAC-PAC®, which is a self-cleaning HEPA filtered vacuum. Additionally, the system can also be connected to other high capacity industrial quality vacuum systems.[2] The Corner-Cutter® may offer potential for supporting the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

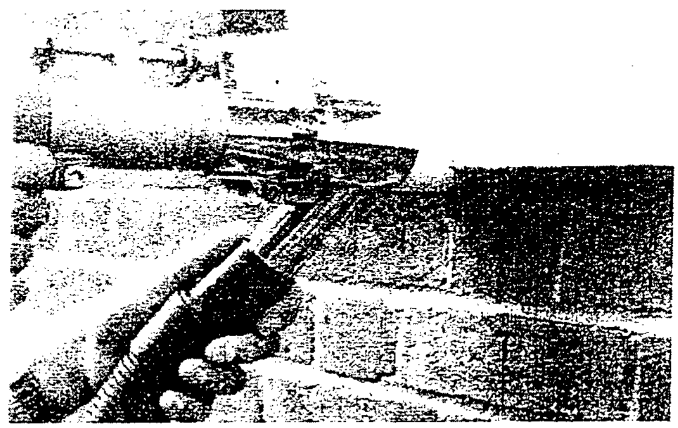


Figure 6.39.1. The Corner-Cutter®, manufactured by Pentek, is a dustless surface decontamination system used to safely remove lead-based paints, chemical spills, epoxy coatings, radioactivity, and other hazardous contaminants from both steel and concrete surfaces.

6.39.2 Moose.

The Moose® is a dustless surface decontamination system used to clean/decontaminate large concrete floors and slabs. The Moose®, shown in Figure 6.39.2, employs mechanical technology and utilizes a single-step floor scarification process with integral vacuum control in order to remove protective coatings, chemical residues, PCBs, and other hazardous material. Concrete is removed in increments of 1/16 to 3/16-inch. Additionally, tough epoxy and urethane coatings can also be stripped in 18 inch passes.

This system is comprised of 3 sub-systems, the scabbling head assembly, the on-board HEPA vacuum system, and the six-wheeled chassis. The scabbling head is equipped with seven independent reciprocating tungsten carbide-tipped bits. The bits are hammered into the surface at the rate of 1,200 impacts per minute through pistons that are driven by compressed air. The cleaning process generates little waste and can be operated using a remote.

The dust and debris generated during this process are captured by the high performance, two-stage positive filtration HEPA vacuum system that deposits the waste directly into an on-board 23-gallon (87 liter) waste drum. The first stage efficiency is 99.5 percent at 1 micron, and the second stage HEPA efficiency is 99.7 percent efficient at 0.3 microns. The first stage filters are continuously and automatically cleaned by reverse- flow pulses of high pressure air, which allows the filter to last up to one year. Additionally, this system also features an automatic full-drum alarm and a patented dustless drum exchange feature that completely eliminates operator exposure to hazardous material.

The six wheel chassis is powered by dual DC motors. Independent skid steering allows the Moose® to pirouette 360 degrees about its geometric center. The scabbling head chassis assemblies are designed to isolate the vibrations generated by the scabbling head, which allows the operator to maintain positive control over the direction and depth of cut during aggressive scabbling operations.

The Moose® is capable of scabbling to within 6 inches (150mm) of walls and other obstructions, and can easily fit through a standard door. Multiple tool ports provide direct interface to Penteks smaller, manually operated scarifiers: the Squirrel-III® floor scabbler and the Corner-Cutter® needle gun, which are designed to scabble hard to get areas that cannot be accessed by the Moose®.[3] The Moose® may offer potential for supporting the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

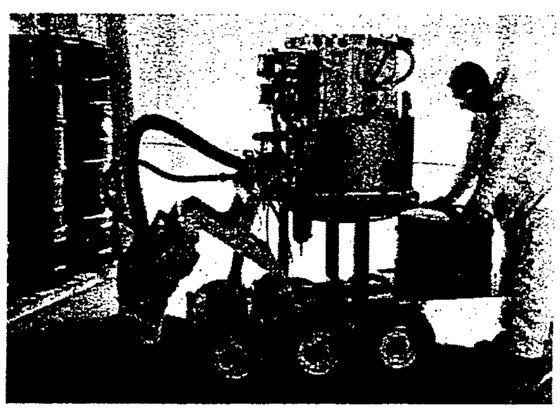


Figure 6.39.2. The Pentek Moose® is a dustless surface decontamination system used to clean/decontaminate large concrete floors and slabs. Photo courtesy of Pentek, Inc.

6.39.3 Roto-Peen Scaler.

The Roto-Peen Scaler, shown in Figure 6.39.3, is a lightweight, man-portable system for removing protective coatings and paints from steel, concrete, brick, and wood in an environmentally safe manner. The Roto-Peen Scaler, commercially available in the U.S. by Pentek, employs mechanical technology and is effective for flat areas and large vertical surfaces, including beams, girders, and tank shells. Additionally, this system is small enough that it can be operated near walls or within confined spaces.

The Roto-Peen Scaler is equipped with 3M™ Heavy Duty Roto-Peen Flaps, each studded with rows of tough tungsten carbide cutters and mounted on a rotating hub. The system removes paint, corrosion, oxide, and mill scale through the impact of the tungsten carbide on the work surface. This mechanical action occurs within an evacuated enclosure designed to prevent the escape of dust, debris, and airborne contamination into the environment.

The Roto-Peen system incorporates speed adjustments to vary surface profile from 0.5 to 4 mils. The depth control allows for exact positioning of the cutters to properly dress the working surface. An adjustable handle is also provided with 3 distinct positions to allow for access to hard-to-reach-areas. This system includes a safety lock throttle to prevent accidental start-ups and a 1.5 inch vacuum port cuff for standard vacuum hook-up.

The Roto-Peen Scaler can clean 40 to 50 square feet per hour of flat surfaces. The cutting width is 2 inches and the revolutions per minute (RPM) at which the system operates is user adjustable up to 2,400 RPM. The following flaps are used for cutting media:

Type A Flaps for concrete scarification.
Type B Flaps for removal of tight mill scale and greater degree of surface profile.
Type C Flaps for standard removal of general coatings.
Type D Flaps for heavy coatings requiring a deeper surface profile on concrete/steel.

The Roto-Peen Scaler requires 30 standard cubic feet per minute of air at 90 psig. The system requires a 0.5 inch diameter air supply hose, along with an in-line Lubricator-Regulator-Filter. The user must also supply a minimum of 75 cubic feet per minute of vacuum in order to ensure containment of dust and debris. This unit will interface directly with the Pentek VAC-PAC® self-drumming/HEPA vacuum system or other high-capacity, industrial HEPA vacuums.[3] The Roto-Peen Scaler may offer potential for supporting the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

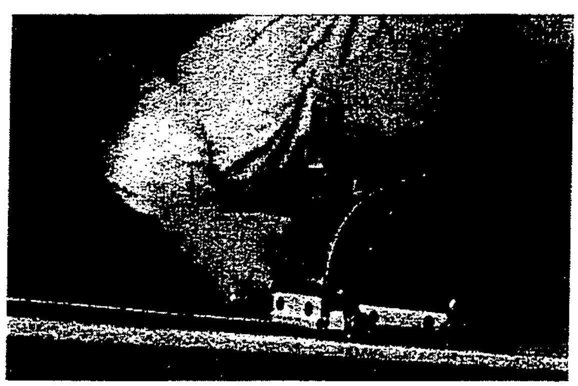


Figure 6.39.3. The Pentek Roto-Peen Scaler is a lightweight, man-portable system for removing protective coatings and paints from steel, concrete, brick, and wood in an environmentally safe manner. Photo courtesy of Pentek, Inc.

6.39.4 Squirrel – III.

The Squirrell III is a dustless surface decontamination system used to safely scabble concrete floors and slabs. The Squirrel III employs mechanical technology and consists of a pneumatically operated scabbler that scarifies concrete floors and slabs in an environmentally safe manner. The Squirrel III is designed for small jobs and fitting into tight spaces near corners, wall/floor joints, floor penetrations, equipment pedestals, steps, and under protruding equipment.

The Squirrel III, shown in Figure 6.39.4, uses high-speed, reciprocating tungsten-carbide tipped pistons to pulverize protective coatings, laitance, and concrete substrate in a single step process. This system utilizes a unique vacuum flow design that provides for high efficiency control of dust, debris, and airborne contamination. This system can clean 20 to 30 square feet per hour at 1/16-inch surface removal. There are 3 nine point, tungsten carbide-tipped scabbling bits located in the Squirrel III, each with a diameter of 1.75 inches. This system requires 60 standard cubic feet per minute of air at 80 psig. The user of the system must supply 75-90 cubic feet per minute of vacuum flow if dust/debris contamination control is desired. The system interfaces with vacuum systems through a standard 1.5 inch vacuum hose. The system is 12 inches in length, 6 inches in width, and requires 12 inches in height below any obstructions. The Squirrel III system weighs approximately 50 pounds.[a] The Squirrel III system may offer potential for supporting the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

Figure 6.39.4. The Pentek Squirrel III is designed for small jobs and fitting into tight spaces near corners, wall/floor joints, floor penetrations, equipment pedestals, steps, and under protruding equipment. Photo courtesy of Pentek, Inc.

6.39.5 WallWalker.

The WallWalker is a dustless surface decontamination system that employs mechanical technology coupled with robotic wall locomotion technology. This system, shown in Figure 6.39.5, provides a completely automated surface treatment process to large vertical surfaces, such as tanks, stacks, buildings, and beams. This commercial system is programmable to adapt to surfaces of unlimited height and width, and is capable of conforming to surface irregularities. Process modules are available to perform 100 percent dustless surface preparation, paint application, and inspection tasks. The locomotion system utilizes two gear motors to feed cable to a central module that is configurable for controlled abrasive, hydro, and CO_2 blasting, as well as mechanical scabbling operations. A computer with input grid coordinates controls the cable length, adjusting them as necessary for efficient locomotion of the unit across surfaces with a high degree of precision and repeatability.

The WallWalker system can prepare and recoat surfaces in 24-inch passes with high production rates. All hazardous dust and debris is contained by the vacuum seal between the robot and the surface. The dust and debris is immediately conveyed by hose directly into the Pentek self-cleaning and drumming HEPA vacuum and waste collection system, the VAC-PAC®.

The WallWalker system can handle working loads in excess of 500 pounds, providing the flexibility to manage a wide variety of process modules (e.g., hydroblasting units, automatic welders, inspection instrumentation, etc.)

The WallWalker locomotion system is able to traverse vertical walls of unlimited height and width: dry docks, ship hulls, fuel storage tanks, waste storage basins, skyscrapers, and multi-story buildings are targeted structures.

The WallWalker path control is a key technological breakthrough that is embodied in the WallWalker system. The precision of the WallWalker is on the order of +/- 1 inch over surfaces of 100 square feet. The path shape, process velocity, and process accelerations are all user selectable. During coatings applications, a 24-inch spray pattern working at a 60 feet/minute path velocity will cover over 7,000 square feet per hour.[3] The WallWalker system may offer potential for supporting the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

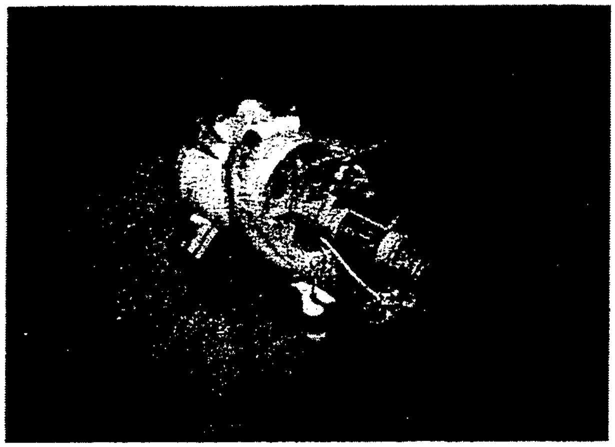


Figure 6.39.5. The Pentek WallWalker is a dustless surface decontamination system that provides a completely automated surface treatment process to large vertical surfaces, such as tanks, stacks, and buildings. Photo courtesy of Pentek, Inc.

6.40 Plysu PLC – UNITED KINGDOM

6.40.1 DECAS Decontamination Unit

The DECAS decontamination unit, shown in figure 6.40.1, is an inflatable decontamination shower commercially available and is manufactured in the United Kingdom by Plysu PLC. The unit is designed for skin and personnel decontamination and employs mechanical technology. The DECAS is equipped with a step-down reducer which enables the use of various pressures in the decontamination process. Hose brushes and trigger-operated sluice eyewash units can be found inside the unit. In addition, glove sleeves can be incorporated into the design of the unit so that medical care may continue throughout the decontamination process without risk to external personnel. The unit can also accommodate clear-screened unobstructed sides enabling protected personnel to accompany contaminated individuals throughout the decontamination process.[1] The DECAS decontamination unit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Fixed Site Decon	

Figure 6.40.1. The DECAS Decontamination Unit is designed to decontaminate skin and personal equipment using pressurized washing. Photo courtesy of Plysu PLC. Photo reproduced with permission from Jane's Information Group.

6.40.2 PLYCHEM DPI Decontamination Unit

The PLYCHEM DPI, shown in figure 6.40.2, is an inflatable decontamination shower commercially available and is manufactured in the United Kingdom by Plysu PLC. The unit is designed for skin and personnel decontamination. The decontamination unit employs chemical technology. The PLYCHEM DPI is constructed from durable polymer material and needs minimal training for use. At a rate of 40 liters per minute, a continuous pressurized flow of decontaminant solution is used in conjunction with brush units to decontaminate personnel inside the shower. External personnel can carry out decontamination through rubber glove sleeve units positioned in the sides of the structure. The unit can be assembled using BA bottles or a compressed airline supply. Stability of the unit is achieved through a ballast skirt surrounding the structure.[1] The PLYCHEM DPI decontamination unit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Fixed Site Decon	

Figure 6.40.2. The PLYCHEM DPI Decontamination Unit is designed to decontaminate skin and personal equipment using pressurized washing. Photo courtesy of Plysu PLC. Photo reproduced with permission from Jane's Information Group.

6.41 Remploy Limited – UNITED KINGDOM.

6.41.1 <u>Decontamination Kit, Personal No 1 Mark 1</u>.

The Personal No 1 Mark 1 is a decontamination kit used by field personnel in the event of a chemical warfare attack. The kit, shown in Figure 6.41.1, is manufactured in the UK by Remploy Limited and is in service with the UK armed forces. The kit employs sorbent technology and is comprised of a sealed plastic bag that contains four pads filled with fuller's earth. Dabbing the pad over the contaminated areas dispenses fuller's earth on the contaminated area.[1] The Personal No 1 Mark 1 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

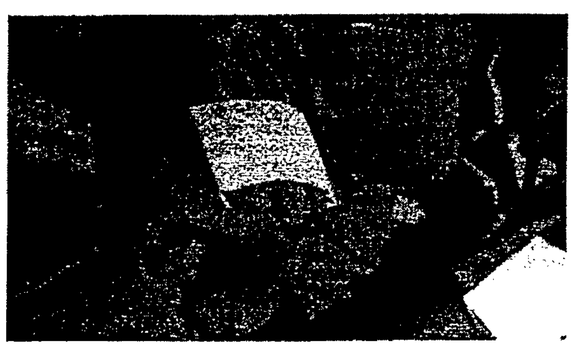


Figure 6.41.1. The Personal No 1 Mark 1 is comprised of a sealed plastic bag that contains four pads filled with fuller's earth.

6.42 Research Institute for Chemical Defense - CHINA.

6.42.1 M-73-1 Decontamination Vehicle.

The M-73-1 Decontamination Vehicle is designed to decontaminate fixed sites (i.e. terrain). The vehicle was developed in China by the Research Institute for Chemical Defence and is currently in service with the Chinese armed forces. The M-73-1, shown in figure 6.42.1, employs chemical technology and disseminates decontamination solutions over contaminated areas of terrain via spray bars. The vehicle is equipped with a 2.5 m^3 tank to hold the decontamination solutions. A two-man crew is required to operate the spray bars and to control the flow of the decontaminants over the contaminated areas. The vehicle's gross weight is 9,300 kg and is 9.86 m long, 2.4 m wide, and 2.42 m high.[1] The M-73-1 Decontamination Vehicle is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

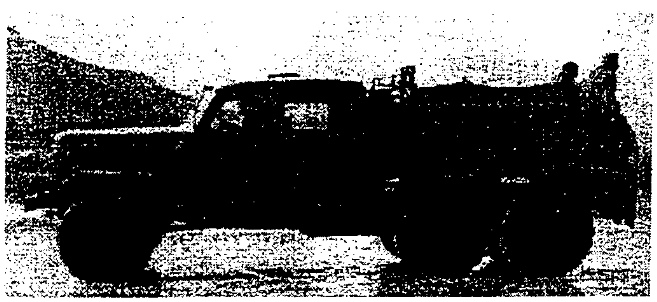


Figure 6.42.1 M-73-1 Decontamination Vehicle. Photo reproduced with permission from Jane's Information Group.

6.42.2 M-82 Personnel Shower Vehicle.

The M-82 Personnel Shower Vehicle, shown in Figure 6.42.2, is used to decontaminate personnel in the event of being exposed to chemical or biological agents. The vehicle, developed in China by the Research Institute for Chemical Defence, is in service with the Chinese armed forces. The vehicle employs mechanical technology and showers the victims with water. The M-82 comprises of an enclosed shower area, resembling a box, mounted onto a 2,500 kg truck. In use, the back of the shower unit extends out behind the truck and is supported on folding legs. The extended area allows personnel added room to change clothes. The M-82 is equipped with a water pump and a heater. The water is drawn through a flexible hose connected to the front of the shower box unit.[1] The M-82 Personnel Shower Vehicle is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

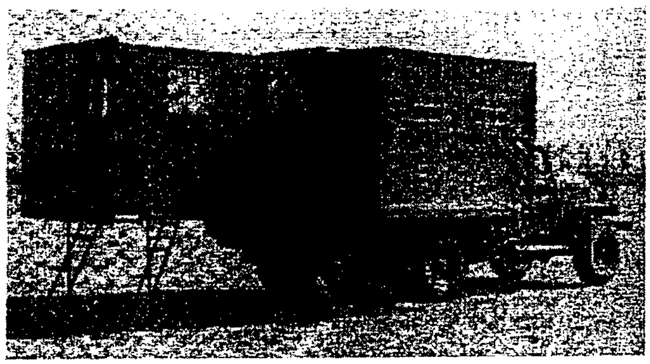


Figure 6.42.2. The M-82 Personnel Shower Vehicle is comprised of an enclosed shower area, resembling a box, mounted onto a 2,500 kg truck. Photo reproduced with permission from Jane's Information Group.

6.43 Richmond Packaging (UK) Limited – UNITED KINGDOM.

6.43.1 Decontamination NBC, Apparatus, Portable, No 2 (DAP 2).

The DAP 2, shown in Figure 6.43.1, is used to decontaminate exterior equipment in the event of a chemical agent attack. The system, manufactured in the UK by Richmond Packaging (UK) Limited, is in service with the UK armed forces. The DAP 2 employs chemical technology. The system is comprised of a stirrup pump, hoses, and a brush wand. The system pumps decontaminant solutions out of a container through the brush wands and onto the contaminated surface. Military personnel scrub the contaminated areas with the brushes and then rinse off any residue with copious amounts of water.[1] The DAP 2 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

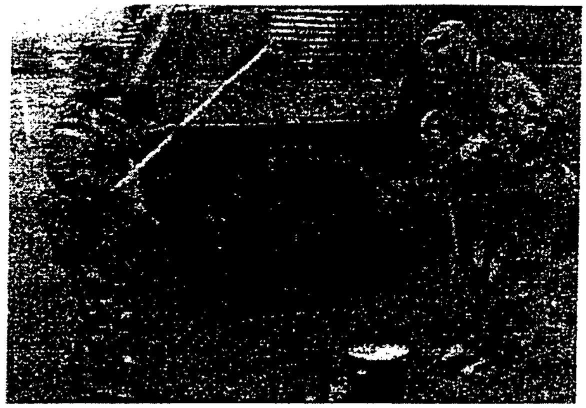


Figure 6.43.1. Richmond Packaging's DAP 2 system is comprised of a stirrup pump, hoses, and a brush wand to decontaminate exterior equipment. Photo reproduced with permission from Jane's Information Group.

6.43.2 Decontamination Kit, Personal No 2 Mark 1.

The Personal No 2 Mark 1 is a decontamination kit used by UK field personnel. The Personal No 2 Mark 1, shown in Figure 6.43.2, is used to decontaminate personal equipment and employs sorbent technology. The kit is comprised of a flat polythene dispenser containing 113 grams of fuller's earth. The kit is generally used with the Personal No 1 Mark 1 Decontamination Kit.[1] The Personal No 2 Mark 1 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

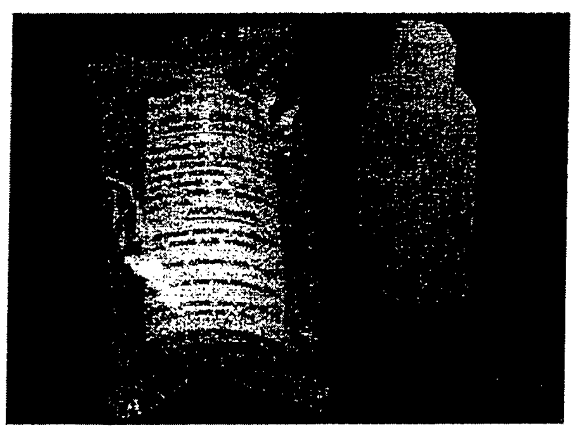


Figure 6.43.2 The Personal No 2 Mark 1 is used by UK field personnel to decontaminate personal equipment. Photo reproduced with permission from Jane's Information Group.

6.44 RMC Medical Inc. - UNITED STATES.

6.44.1 Hazmat Decon Shower.

The Hazmat Decon Shower, manufactured by RMC Medical, is designed to decontaminate personnel. The Hazmat Decon Shower employs mechanical technology and delivers a high-pressure water spray. The Hazmat Decon Shower is made of 1 ½ in PVC tubing and is transportable in a canvas duffel bag. The Hazmat Decon Shower, shown in Figure 6.44.1, can be erected in several minutes. The Hazmat Decon Shower is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.44.1. RMC Medical's Hazmat Decon Shower.

6.45 Rosvoorouzhenie – RUSSIAN FEDERATION AND ASSOCIATED STATES.

6.45.1 Protector-N Truck-Mounted Decontamination Apparatus.

The Protector-N Truck-Mounted Decontamination Apparatus, shown in Figure 6.45.1, is designed for the decontamination of vehicles, aircraft, equipment, hard-surfaced roads, and terrain. The apparatus is manufactured by the state factories of the Russian Federation and Associated States (RFAS), marketed by Rosvoorouzhenie of Moscow, RFAS, and is in production. The apparatus employs low-temperature thermal technology coupled with chemical technology. The system delivers a high-pressure spray of hot gas with decontaminants to decontaminate vehicles and equipment.

The Protector-N uses a gas-turbine aircraft engine mounted on a KrAZ-260 (9,000 kg truck chassis) and includes an operator's cabin. The apparatus is equipped with a decontaminant tank along the side of the truck chassis. Two turbine engines are normally used for decontamination operations. They are spaced 50 m apart and the vehicles to be decontaminated pass through the hot gas/decontamination solution. The two engines can be prepared for operation or removed from operation in 10 to 12 minutes. The Protector-N has a capacity of 10 to 40 vehicles or 5 to 15 air crafts per hour and has an operating temperature range from -40°C to +50°C.[1] The Protector-N Truck-Mounted Decontamination Apparatus is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

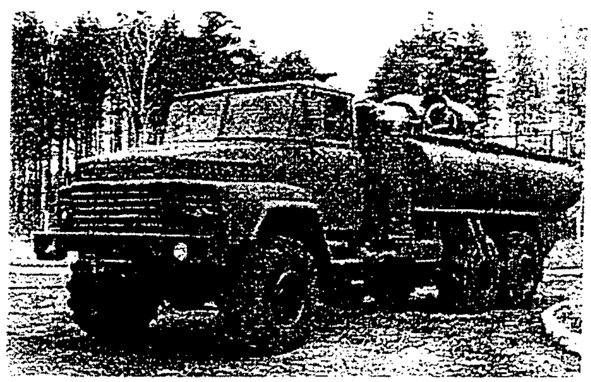


Figure 6.45.1. The Russian Protector-N Truck-Mounted Decontamination Apparatus. Photo reproduced with permission from Jane's Information Group.

6.45.2 BKSO Decontamination Kit.

The Russian BKSO Decontamination Kit, shown in Figure 6.45.2, is designed to enable vehicle crews to conduct decontamination immediately following a chemical attack. The BKSO Kit employs both chemical (primary) and mechanical (secondary) technologies. Power for operating the decontamination equipment is provided by the vehicle exhaust system and compressed air brake system. A vehicle mounted metal case houses the decontamination equipment, decontaminating solutions, and the components needed to connect the kit to the vehicle's exhaust and compressed air brake systems. The kit is deployed on trucks and armored personnel carriers. The kit mixes the decontaminating solution with water and delivers the decontaminating mixture at 0.6 to 1.5 liters/minute. The BKSO Decontamination Kit weighs 26 kg (in the metal case) and is 650 mm by 530 mm by 190 mm high with an operating temperature range from -40°C to +50°C.[1] The BKSO Decontamination Kit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.45.2. The Russian BKSO Decontamination Kit is designed to enable vehicle crews to conduct decontamination immediately following a chemical attack. Photo reproduced with permission from Jane's Information Group.

6.45.3 Decontamination Apparatus, Truck-Mounted, Models TMS-65 and TMS-65M.

The Truck-Mounted Decontamination Apparatus is designed for the decontamination of vehicles, towed weapons, and equipment. The apparatus is manufactured by the state factories of the Russian Federation and Associated States (RFAS), marketed by Rosvoorouzhenie of Moscow, RFAS, and is in service with RFAS and former Warsaw Pact armed forces. The system employs low-thermal technology coupled with chemical technology. Both systems deliver a high-pressure spray of hot gas with decontaminants to decontaminate vehicles and equipment.

The TMS-65 Model uses a gas-turbine aircraft engine mounted on a Ural-375 (4,000 kg truck chassis) and includes an operator's cabin. The TMS-65M Model uses the same gas-turbine engine mounted on a larger Ural-4320 (4,500 kg truck chassis). The models are equipped with a 1,500 liter decontaminant tank and a 4,000 liter water tank, which are located behind the truck chassis. Two turbine engines are normally used during decontamination practices and are spaced 50 m apart while the vehicles to be decontaminated pass through the hot gas/decontamination solution. The process takes between 30 seconds and 3 minutes depending on the level of contamination.[1] The Truck-Mounted Decontamination Apparatus is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.46 Spilfyter – UNITED STATES.

6.46.1 Absorbents.

Spilfyter of Wisconsin manufactures absorbents for chemicals under the trade name "Kollect-A-Kem". Kollect-A-Kem absorbents, shown in Figure 6.46.1, employ sorbent technology and are available in many different forms: particulate, pillows, socks, strips, as well as kits that combine the forms into an all-purpose spill kit. The Kollect-A-Kem sorbents absorb up to 12 times their own weight. The Kollect-A-Kem adsorbents may offer potential for supporting the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.46.1. Spilfyter's Kollect-A-Kem absorbents. Photos courtesy of Spilfyter.

6.47 S.T.A.S. Fire Suppression Services – UNITED STATES.

6.47.1 High-Volume Sprayer (HVS).

The HVS is a commercially available vehicle-mounted sprayer that could be potentially used for the decontamination of fixed site and exterior equipment. The unit is manufactured in the U.S. by S.T.A.S Fire Suppression Services and is presently used to douse fires. The system disseminates water, decontaminants, or foam onto contaminated areas, and depending upon the decontaminant used, the system may employ either mechanical or chemical technologies. The system is equipped with a sprayer assembly that can be moved 180° horizontally and 65° vertically. The system is equipped with a 250-gallon tank. Approximately 1.0 to 4.3 gallons is required to cover 100 ft^2 at 2.5 to 10 miles per hour. The sprayer can be operated from inside the vehicle cabin using a hand held controller. The High Volume Sprayer may offer potential for supporting the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

6.48 State Factories – CZECH REPUBLIC and SLOVAKIA.

6.48.1 LINKA 85 NBC Decontamination System.

The LINKA 85 NBC Decontamination System is designed for the decontamination of vehicles by driving them through a spray frame. The LINKA 85 NBC Decontamination System, shown in Figure 6.48.1, is manufactured by the state factories of the Czech Republic and Slovakia and is currently in service with the Czech and Slovak armed forces. The LINKA 85 NBC Decontamination System employs chemical (primary) and mechanical (secondary) technologies. Decontaminants or water is dispensed through spray bars by means of a pumping and decontaminant mixing unit.[1] The LINKA 85 NBC Decontamination System is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

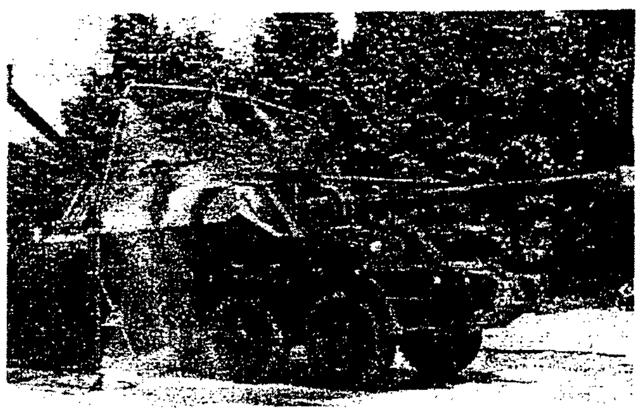


Figure 6.48.1. The LINKA 85 NBC Decontamination System, manufactured by the state factories of the Czech Republic and Slovakia, is designed for the decontamination of vehicles by driving them through a spray frame. Photo reproduced with permission from Jane's Information Group.

6.49 State Factories – POLAND.

6.49.1 Decontamination Apparatus, Truck Mounted, Model IRS.

The Decontamination Apparatus, Truck Mounted, Model IRS is designed to decontaminate exterior equipment as well as fixed sites. The Model IRS, shown in Figure 6.49.1, is manufactured in Poland by state factories and is currently in service with Polish armed forces. The system may employ mechanical or chemical technologies depending on what decontamination solutions are chosen. The Model IRS is equipped with a 2,500 liter tank, an engine driven pump, a hand pump, a heater, pipes, hoses, and additional shower equipment. The system pump is capable of delivering liquid solutions at a rate of 600 liters per minute at a pressure of 4 kg/cm^2. The heater is capable of raising the temperature of 2,000 liters of solution in one hour to 70 °C. The decontamination solutions are sprayed over contaminated surfaces using fourteen 10 mm hoses. Each hose is equipped with a spray pipe, nozzle, and a nozzle brush. For large buildings, three 20 m hoses can be connected on to the apparatus, each with a

25 mm diameter. The entire system weighs 9,500 kg.[1] The Decontamination Apparatus, Truck Mounted, Model IRS is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

Figure 6.49.1. The Polish Decontamination Apparatus, Truck Mounted, Model IRS is capable of delivering liquid solutions at a rate of 600 liters per minute at a pressure of 4 kg/cm^2. Photo reproduced with permission from Jane's Information Group.

6.49.2 Decontamination Apparatus, Model UDU.

The Model UDU is an apparatus designed to decontaminate personal equipment against radioactive particle contamination. The Model UDU could potentially be utilized to decontaminate personal equipment against chemical or biological agents. The system is manufactured in Poland by state factories and is currently in service with Polish armed forces. The Model UDU employs mechanical technology and is equipped with an internal combustion engine, a system of beaters, and a vacuum system. The contaminated clothing is first beaten so that any particles become loosened and then vacuumed thoroughly to remove any contamination. A small container is used to collect the contamination. The Model UDU can decontaminate 120 pieces of clothing per hour and the entire system weighs 270 kg.[1] The Model UDU may offer potential for supporting the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.50 State Factories – RUSSIAN FEDERATION AND ASSOCIATED STATES.

6.50.1 Decontamination Apparatus, Backpack, Model RDP-4V.

The RDP-4V Backpack Decontamination apparatus is designed for the decontamination of vehicles, equipment, weapons, small buildings, and small terrain. The RDP-4V is manufactured by the state factories of the Russian Federation and Associated States and is in service with the Russian Federation armed forces. The RDP-4V, shown in Figure 6.50.1, employs chemical (primary) and mechanical (secondary) technologies. The system utilizes a spray pipe and nozzle to deliver decontaminating solutions. The apparatus is pumped with the left hand at 25 to 30 strokes/minute, providing a flow of 0.7 liter/minute. The apparatus weighs 8.5 kg (17 kg full) and is 290 mm x 190 mm by 355 mm high. The apparatus includes a tank, filter screen, cap, air pump, outlet tube and hose, and a spray pipe and nozzle. Tools are attached to the bottom of the tank.[1] The RDP-4V Backpack Decontamination apparatus is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

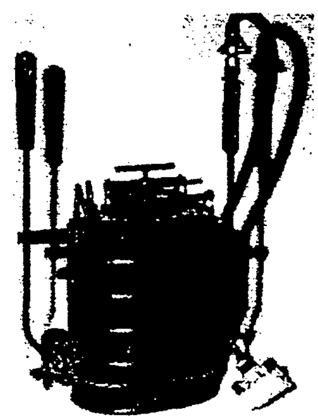


Figure 6.50.1. The Russian RDP-4V Backpack Decontamination apparatus is designed for the decontamination of vehicles, equipment, weapons, small buildings, and small terrain. Photo reproduced with permission from Jane's Information Group.

6.50.2 Decontamination System Portable, Model DKV.

The Decontamination System Portable, Model DKV is a mobile decontamination system used to decontaminate exterior equipment. The DKV is manufactured in the Russian Federation and Associated States and is currently in service with the Russian Federation and Associated State forces. The DKV delivers a high-pressure spray of decontamination solutions. Depending on which decontamination solutions are utilized, the DKV system may employ either mechanical or chemical technologies. The DKV employs high-pressure spray technology. A specially equipped truck and trailer system is used to transport the 78 cylindrical tanks that comprise this system. Each tank is filled with a decontaminant solution and comes with either one or two spray pipes. The tanks are pressurized using either the air brake system from a vehicle or a separate compressor. The spray pipes are equipped with brushes for thorough cleansing of contaminated surfaces. Each of the cylinders holds approximately 30 liters of decontaminant and can be refilled after each use. The contents of two cylinders are enough to decontaminate one truck.[1] The Decontamination System Portable, Model DKV is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.50.3 <u>Decontamination Apparatus, Truck Mounted, Models ARS-12D, ARS-12U, and ARS-12M</u>.

The Decontamination Apparatus, Truck Mounted, Models ARS-12D, ARS-12U, and ARS-12M are mobile decontamination systems used to decontaminate exterior equipment. The ARS-12 Models were manufactured by the Russian Federation and Associated States. Depending on what decontaminants are used by each system, the ARS-12 Models may employ either mechanical or chemical technology. These systems are no longer in production, but are currently in service with the Russian Federation and Associated States, along with former Warsaw Pact armed forces. The Decontamination Apparatus, Truck Mounted, Models ARS-12D, ARS-12U, and ARS-12M, shown in Figure 6.49.3, employ high-pressure spray technology. These items can also be used for carrying water, fire fighting, and providing cold showers. The three models are basically similar but are mounted on different truck chassis. The ARS-12D is mounted on a ZIL-151 (6x6) 2,500 kilogram truck chassis, while the ARS-12U is mounted on a ZIL-157 (6x6) 2,500 kilogram truck chassis. The ARS-12M is mounted on a Praga V3S (6x6) 3,000 kilogram truck chassis and may have been produced for the Czech Republic armed forces.

Carried on each of the vehicles is a 2,500 liter tank with two baffles and a large manhole for accessing and filling. The vehicles also contain a self priming pump that is driven by the trucks engine, hand pump, depth gauge, piping system, hoses, nozzles, and other spare and accessory parts. The drive shaft for the main pump turns at 1,400 to 1,600 rpm and can pump 300 to 400 liters/minute. The hand pump, operated at 45 strokes/minute, can deliver 4.5 to 5.5 liters/minute. Decontaminants are mixed in the tank as water is poured into the tank. A thorough mixture is made by internally recycling the solution through the pump, otherwise vehicle motion and the mixing that occurs during the filling of the tank is all that is required to ensure a good mixture inside the tank.

In order to clear contaminated roads or terrain a wide area nozzle can be fitted directly to the tanks main discharge pipe. The vehicle is then driven over the affected road or terrain and the decontaminant is spread over the contaminated area. A full tank can decontaminate an area 500 meters long and 5 meters wide. When decontaminating vehicles or other equipment, eight hoses can be connected to the truck. Each hose can by up to 18 meters in length. These hoses are usually equipped with spray pipes, nozzles, and nozzle brushes. Up to four vehicles can be decontaminated at the same time.

If the truck is used to decontaminate fixed site installations or to fight fires, four 25 millimeter hoses can be fitted to the truck. Racks located on the top of the truck hold decontaminant drums and equipment that can be used for operations in remote areas.[1] Decontamination Apparatus, Truck Mounted, Models ARS-12D, ARS-12U, and ARS-12M are intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

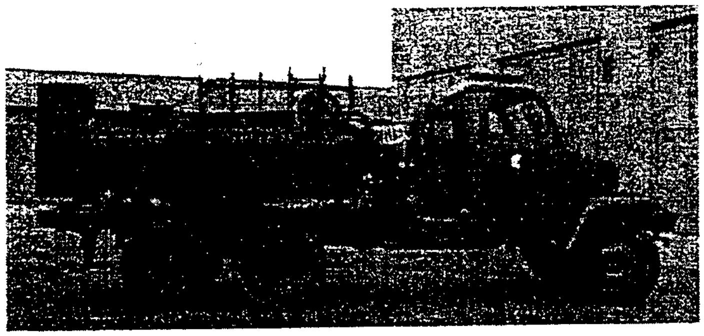


Figure 6.50.3. The Decontamination Apparatus, Truck Mounted, Models ARS-12D, ARS-12U, and ARS-12M are mobile decontamination systems used to decontaminate exterior equipment. Photo reproduced with permission from Jane's Information Group.

6.50.4 Decontamination Apparatus, Truck Mounted, Model ARS-14.

The Decontamination Apparatus, Truck Mounted, Model ARS-14 is a mobile decontamination system used to decontaminate exterior equipment. The ARS-14 is no longer manufactured but is currently in service with the Russian Federation and Associated State forces, Czech Republic, and Slovakia. Depending on the decontaminant utilized, the ARS-14 may employ either chemical or mechanical technology. The ARS-14, shown in Figure 6.49.4, is an upgrade from an earlier decontamination apparatus, the Model ARS-12 U. The ARS-14 is mounted on a 6x6 vehicle and is equipped with a decontaminant tank, which has been upgraded from 2,500 liters to 2,700 liters and weighs 2,500 kilograms when full. Additional decontaminant drums are also carried on the truck in specially fitted racks. The system is also equipped with outlet pipes that are carried on the truck and are fitted to the equipment by hoses. A wide area nozzle is located at the front and rear of the vehicle and eight hoses are rolled up onto four drums. One notable addition to this vehicle was the addition of a rubber hose that can be connected to the exhaust system in order to thaw any parts or equipment that may have become frozen. The truck weighs 10,185 kilograms and is 6.856 meters in length, 2.47 meters in width, and 2.48 meters in height.[1] The Decontamination Apparatus, Truck Mounted, Model ARS-14 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.50.4. The ARS-14 is an upgrade from an earlier decontamination apparatus, the Model ARS-12 U. Photo reproduced with permission from Jane's Information Group.

6.50.5 Individual Decontamination Kit.

The Individual Decontamination Kit (IPP) is a lightweight, man-portable, self-contained decontamination kit used for the decontamination of skin and personal equipment. The IPP is manufactured in Russian Federation and Associated States and is currently in service with the Russian Federation and Associated State Forces. The kit, shown in Figure 6.50.5, employs mechanical technology and is equipped with decontaminants for nerve agents, blister agents, and biological agents. The case includes a glass and plastic vial, which contain a glass ampoule. Crushing the ampoule mixes the two solutions resulting in a mixture that can be used once the plastic vial has been punctured with the metal point in the case lid. The solution is applied to the affected area using gauze pads. Approximately 5 m^2 can be covered with the mixture.

The nerve gas decontaminant is first spread from the glass vial and then from the plastic vial. The kit is also equipped with four anti-smoke gauze-wrapped ampoules which can be used to protect the soldier from warfare gas. The ampoule is crushed and placed inside an individuals protective mask. The resultant inhalations can overcome the effects of most irritant smokes. Each of the ampoules contains a mixture of chloroform, ethanol, ethyl ether, and ammonia water.[1] The Individual Decontamination Kit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

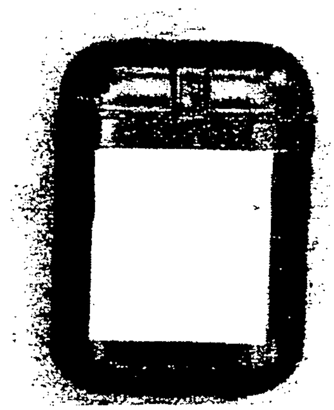


Figure 6.50.5. The Individual Decontamination Kit (IPP) is a lightweight, man-portable, self-contained decontamination kit equipped with decontaminants for nerve agents, blister agents, and biological agents. Photo reproduced with permission from Jane's Information Group.

6.50.6 Decontamination Packet, Model DPS.

The Decontamination Packet, Model DPS is a lightweight, portable, self-contained decontamination packet used to decontaminate skin and personal equipment. The DPS is manufactured in the Russian Federation and Associated States and is currently in service with the Russian Federation and Associated State Forces. The packet is manufactured from clear plastic and comes sealed. The kit employs sorbent technology. The kit is equipped with a fabric-dusting bag filled with a brown powder, which is capable of absorbing chemical agents. The bag is wiped over contaminated surfaces allowing the powder to absorb any chemical agents. Any residue left on the personal equipped is brushed or wiped off.[1] The Decontamination Packet, Model DPS is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.50.7 Decontamination Kit, Model PKhS.

The Decontamination Kit, Model PKhS is a lightweight, man-portable, self-contained decontamination kit used to decontaminate skin and personal equipment. The PKhS is manufactured in theRussian Federation and Associated States and is currently in service with the Russian Federation and Associated State forces. The kit employs chemical technology (oxidation) and is designed to decontaminate areas that are too large for the Individual Decontamination Kit – IPP. The kit, shown in Figure 6.50.7, is equipped with three 0.5-liter bottles, 4 packets of decontaminant (2 large, 2 small), 2 packets containing 10 gauze pads each, a mixing dish, and a wooden stirrer. One of the 0.5-liter bottles is sealed with a red wax, while the other two bottles are sealed with a white wax. The contents in the red wax sealed bottle can be used to decontaminate nerve agents. In order to decontaminate blister agents, the contents of one of the large decontaminant packets and the contents in one of the small decontaminant packets are mixed together and combined with the contents of one of the white wax sealed bottles in a dish. The final mixture can be applied to contaminated surfaces using a gauze pad. The decontaminant kit carrying case is 305 mm wide, 305 mm high, and 90 mm deep and is packaged in a plywood case.[1] The Decontamination Kit, Model PKhS is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

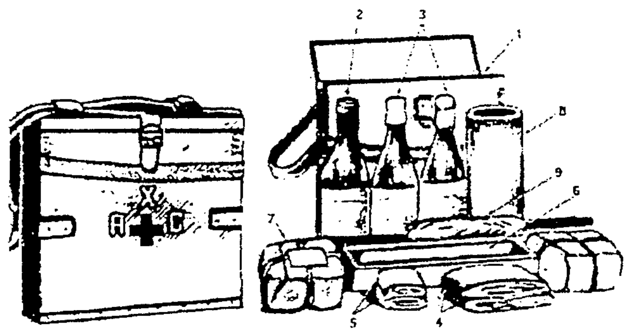


Figure 6.50.7. The Decontamination Kit, Model PKhS is a lightweight, man-portable, self-contained decontamination kit is designed to decontaminate areas that are too large for the Individual Decontamination Kit – IPP. Photo reproduced with permission from Jane's Information Group.

6.50.8 Personal Weapons Decontamination Kit, Model IDP.

The Personal Weapons Decontamination Kit, Model IDP is a lightweight, man-portable, self-contained decontamination kit used for decontaminating exterior equipment. The IDP is manufactured in the Russian Federation and Associated States and is currently in service with the Russian Federation and Associated State forces. The IDP employs mechanical, sorbent, and chemical technologies and is designed for the decontamination of personal weapons. The kit is equipped with five cotton swabs and two ampoules (one red tipped, the other one black tipped). The red tipped ampoules is used to decontaminate blister agents, while the black tipped ampoules is used to decontaminate nerve agents. A contaminated weapon is first wiped with a swab to remove as much contamination as possible. The appropriate ampoule is then used along with decontamination solutions in order to neutralize any remaining agent on the surface. The equipment is then dried and oiled. Each ampoule contains 82 milliliters of decontamination solution. The entire kit weighs 305 grams and the carrying case is 130 mm long, 80 mm wide, and 40 millimeters deep and weighs 305 grams.[1] The Personal Weapons Decontamination Kit, Model IDP is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.50.9 Artillerv Decontamination Kit, Model ADK.

The Artillery Decontamination Kit, Model ADK is a lightweight, man-portable, self-contained decontamination kit used to decontaminate exterior equipment. The ADK, shown in Figure 6.50.9, is manufactured in the Russian Federation and Associated States and is currently in service with the Russian Federation and Associated States armed forces. This kit employs chemical technology and is designed for crews of artillery pieces and large caliber mortars to allow the crews to decontaminate their weapons. The kit is effective against both blister and nerve agents and is housed in a metal case that holds four 1 liter cans of decontaminant solution. Two of the cans are filled with 1 liter of dichloroethane, which is effective against blister agents and V-type nerve agents, while the other two cans are effective against G-type nerve agent. The two cans filled with dichloroethane are capped with red lids and have the number "1" printed on the top. The other two cans are capped with black lids and have the number "2" printed on top. These cans are filled with ready-mixed No. 2 aqueous solution (composed of 2 percent sodium hydroxide, 5 percent monoethanolamine, and 20 percent ammonia), for use against G-type nerve agents. In addition, the case is equipped with two smaller plastic containers, two application brushes (with handle extensions), two metal scrappers, 500 grams of cotton wool, a 150 millimeter long roll of sealing tape, and four cork gaskets. Four rubber blocks are used to keep the cans in place. The metal scrapers are used to remove mud and dirt from the equipment while the decontaminant solutions are being mixed.

The first decontaminant solution (No. 1) is made by combining one 80-gram packet of DT-6 decontaminant powder with one of the cans with a red lid and shaking the mixture for 5 to 10 minutes. The resultant mixture is wiped and scrubbed onto contaminated surfaces. The No. 2 aqueous solution (in the black-lidded cans) is used to remove any No.1 solution as well as decontaminate any G-type nerve agents. The solutions are commonly used in numerical order.[1] The Artillery Decontamination Kit, Model ADK is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

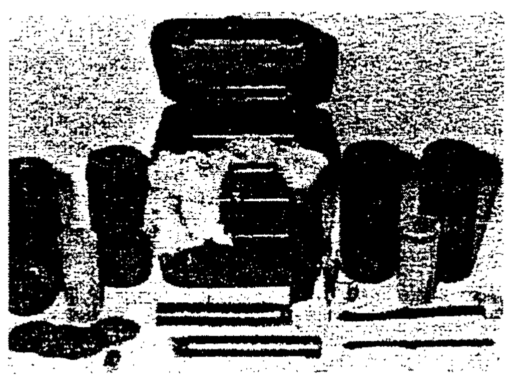


Figure 6.50.9. The Artillery Decontamination Kit, Model ADK is a lightweight, man-portable, self-contained decontamination kit is designed for crews of artillery pieces and large caliber mortars to allow the crews to decontaminate their weapons. Photo reproduced with permission from Jane's Information Group.

6.50.10 The Machine Gun/Mortar Decontaminant Kit, Model PM-DK.

The PM-DK is a lightweight, man-portable, self-contained decontamination kit used to decontaminate exterior equipment. The kit, shown in Figure 6.50.10, is manufactured in the Russian Federation and Associated States and is currently in service with those states. The PM-DK employs chemical technology. The decontamination kit uses the same components as the artillery decontamination kit, however on a smaller scale. Only two solution cans are housed in the metal case and only one application brush that fits directly on the solution can be utilized. Additionally, a cleaning wire is supplied to clean the hollow handle on the brush. Each of the solution cans contains 250 milliliters. In a similar manner to the larger artillery kit, the Model PM-DK solution cans can be refilled and reused. Spare gaskets are supplied in order to reseal the cans. Two types of carrying cases are available for the kit. One of the cases has straight sides with rounded corners and the other case has curved, body contoured sides.[1] The PM-DK is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

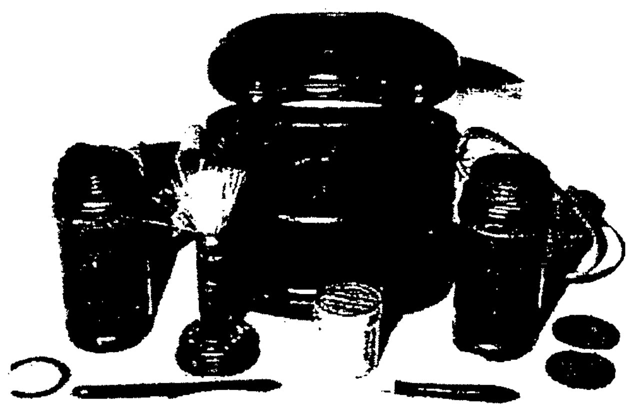


Figure 6.50.10. The PM-DK is a lightweight, man-portable, self-contained decontamination kit uses the same components as the artillery decontamination kit, however on a smaller scale. Photo reproduced with permission from Jane's Information Group.

6.50.11 Decontamination Apparatus, Truck-Mounted, Models DDA-53, DDA-53A, DDA-53B and DDA-66 (DDA Series).

The DDA series are truck-mounted decontamination systems designed to decontaminate skin and personal equipment. The systems, shown in Figure 6.49.11, are manufactured in the Russian Federation Associated States and are in service within those states. The systems employ chemical and mechanical technologies. The system utilizes high-pressure steam cleaning to decontaminate and disinfect items that have become exposed to chemical and biological agents. The DDA series are each equipped with two steam chambers, a vertical boiler, a fuel oil tank, a water pump, a formaldehyde tank, and hoses. The water boiler can hold up to 250 liters of water and produces steam or hot water. The volume of steam generated is sufficient to decontaminate up to 80 uniforms per hour in the summer and 48 uniforms per hour in the winter. The DDA-53 series can also provide hot water for over 100 showers per hour in the summer and 70 showers in the winter. The systems are not equipped with a water tank, therefore a water tank r st be provided. The DDA series is intended to support the following CB decontamination activi s.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

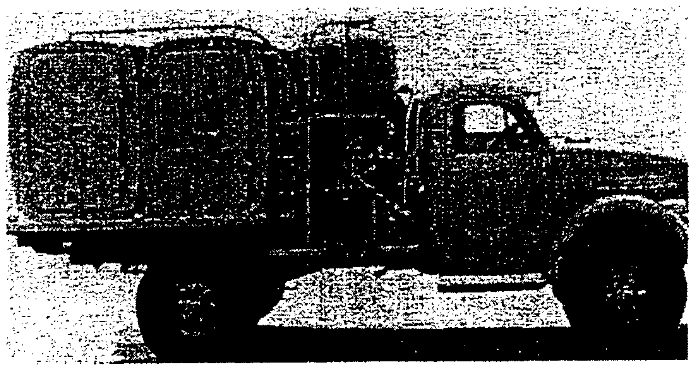


Figure 6.50.11. The DDA series are truck-mounted decontamination systems use high-pressure steam cleaning to decontaminate and disinfect items that have become exposed to chemical and biological warfare agents. Photo reproduced with permission from Jane's Information Group.

6.50.12 Decontamination Station, Model AGV-3M.

The AGV-3M is a decontamination station used to decontaminate personal equipment. The station is manufactured in the Russian Federation and Associated States (RFAS) and is in service in those respective states as well as in Germany under the name AGW-3M. The system employs mechanical technology and delivers steam to decontaminate personal equipment. The station consists of four special vehicles: a Model AGV-3M truck-mounted decontamination steam and hot air generator, two Model AGV-3M truck-mounted decontamination steam chambers, and one cargo truck, which carries a drying tent, a shower tent, and a water tank.

Contaminated clothing is hung inside the steam chambers where steam temperatures range from 160 to 200 °C. After steam treatment, the clothing is moved to the drying tent. The entire system can decontaminate between 50 and 150 uniforms per hour, depending on the nature of contamination. Decontaminants can be added to the steam stream for thorough decontamination.[1] The AGV-3M is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.51 Stella-Meta – UNITED KINDGOM

6.51.1 NBC6F Water Purification Unit (WPU)

The NBC6F, shown in Figure 6.51.1, is a decontamination unit used to purify contaminated drinking water. The system is manufactured in the United Kingdom by Stella-Meta and is currently in service with the British Army. The system is equipped with hoses, pumps, and storage tanks. The unit can be operated in full NBC protective clothing. The NBC6F is capable of treating 2.2 m^3/hour of NBC contaminated water. The system weighs 3,300 and is 4 meters long (w/trailer), 2.5 meters wide, and 2.4 meters high.[1] The NBC6F is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area	✓

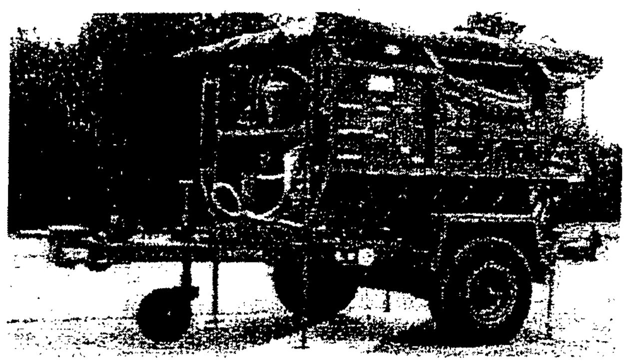


Figure 6.51.1. The NBC6F has been employed by the British Army to purify water that has been contaminated with NBC agents. Photo reproduced with permission from Jane's Information Group.

6.52 Svenska Cargo Forsaljings AB - SWEDEN.

6.52.1 Cargo Mobile Decontamination Station.

The Cargo Mobile Decontamination Station is a decontamination trailer designed for decontaminating skin and personal equipment. The mobile station, shown in Figure 6.52.1, is manufactured in Sweden by Svenska Cargo Forsaljings AB and is still in the prototype stage. The station employs chemical (primary) and mechanical (secondary) technologies. The trailer has two tents, one tent extending out on each side. Each tent is divided into three areas, a disrobing area, shower/decontamination area, and a drying/dressing area. Each tent can accommodate six standing victims or three victims lying down.

The station is equipped with a 500-liter water tank. The water is dispensed to showers at a flow rate of 80 liters per minute and can be heated to 35 °C using a bottled gas heating system. Contaminated water is captured in two collection reservoirs, where it is then pumped to two 3 cubic meter disposal tanks. The trailer mounted Cargo Mobile Decontamination Station weighs 1,500 kg and is 5.8 m long, 2.18 m wide, and 2.6 m high. The Cargo Mobile Decontamination Station is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

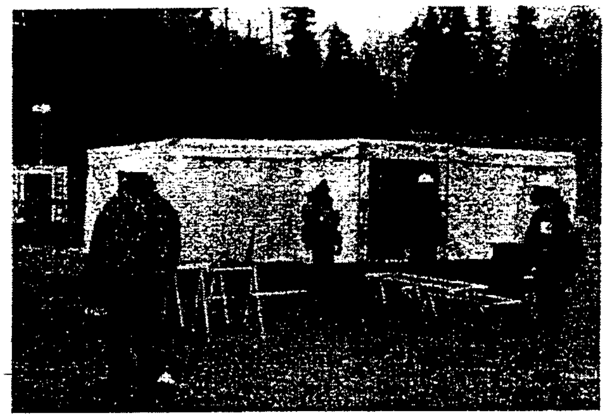


Figure 6.52.1. The Cargo Mobile Decontamination Station is a decontamination trailer designed for decontaminating skin and personal equipment. Photo reproduced with permission from Jane's Information Group.

6.53 TATRA – CZECH REPUBLIC.

6.53.1 Decontamination Apparatus, Truck Mounted, Model TZ-74.

The Decontamination Apparatus, Truck Mounted, TZ-74 is a mobile decontamination system used to decontaminate exterior equipment. This system is manufactured in Czech Republic and Slovakia. The truck chassis is manufactured by TATRA and is currently in service with the Czech, Slovak, and German armies. The TZ-74 decontamination system, shown in Figure 6.53.1, employs chemical (primary) and mechanical (secondary) technologies. The system utilizes high-pressure spray systems to disseminate decontaminants over vehicles and equipment using a small gas turbine engine. The gas turbine engine is mounted in the rear of the truck, which is based on the chassis of the TATRA 148 PPR 15 (6x6). The operator's cabin for the decontamination system is located on the left-hand side of the vehicle as viewed from the rear of the truck looking forward. The additional space located in the rear of the truck contains a 2000-liter fuel tank for supplying fuel to the jet engine and a 5,000-liter tank of decontaminant solution. The gas turbine, designated Type M 701 c-500, can be traversed through 120 degrees, elevated 30 degrees, and depressed 20 degrees. The jet engine can dispense liquids at the rate of 900 liters/hour.

The TZ-74 decontamination system weighs 22,000 kilograms fully loaded and 14,000 kilograms empty. It is 9.5 meters in length, 2.5 meters in width, and 2.95 meters in height. This system requires a two person operational crew and can also be used to create smoke screens when not being used for decontamination operations. The Decontamination Apparatus, Truck Mounted, TZ-74 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.53.1. The Decontamination Apparatus, Truck Mounted, TZ-74 uses high-pressure spray systems to disseminate decontaminant solution over vehicles and equipment using a small gas turbine engine. Photo reproduced with permission from Jane's Information Group.

6.54 TECHNIKA Foreign Trade Company – HUNGARY.

6.54.1 <u>Vehicle Decontamination Kits (MK-67P, MK-67, MK-67CS)</u>.

The TECHNIKA Foreign Trade Company, located in Hungary, manufactures a series of decontamination kits designed for exterior equipment decontamination. The kits are in service with the Hungarian armed forces and are designed to spray decontaminants on contaminated surfaces. The kits employ chemical technology and sprays decontaminants at high-pressure. The MK-67 P is designed to decontaminate armored vehicles. The kit is equipped with a lid, stove, foot pump, petrol burner, and hoses. The stove is used to heat decontamination solutions, which are dispensed using the foot pump and hoses. The foot pump, at 40 strokes per minute, can spray decontaminants at a flow rate of 3 liters per minute. Brushes are attached to the hoses, in order to allow personnel to scrub contamination off of the equipment. The kit can be attached to military vehicles so that immediate decon is possible. The kits weigh 35 kg and is 380 mm long, 800 mm wide, and 220 mm wide.

The MK-67 is a similar to the MK-67P, however, it is used to decontaminate vehicles as well as personal equipment. The kit is stored in a metal container, which is also used as a dish in which decontamination solutions are prepared. The foot pump provided dispenses decontaminants through 2 brushes.

The MK-67C is a smaller version of the MK-67 and is designed to decontaminate small vehicles such as Jeeps. The kit is only equipped with one brush.[1] The Vehicle Decontamination Kits are intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.54.2 Decontamination Vehicle Type FMG-85.

The FMG-85 is a decontamination vehicle designed for the decontamination of exterior equipment. The trailer employs mechanical technology and delivers water at high-pressure. The FMG-85 is utilized as a water tanker and holds 2,000 liters of water. The trailer is equipped with a centrifugal pump, a boiler, a mixer, and pipelines. The pump is capable of suctioning water from reservoirs to a height of 5 m. Using the boiler, the trailer can heat up the entire 2,000-liter water supply to 60 °C in 60 to 80 minutes. The mixer can be used to prepare decontaminant solutions in order to increase the effectiveness of the decontamination procedure.[1] The FMG-85 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.54.3 Decontamination Trailer Type FMU.

The FMU is a decontamination trailer designed for the decontamination of exterior equipment. The trailer, manufactured in Hungry by TECNIKA Foreign Trade Company, is in service with the Hungarian armed forces. The trailer employs mechanical technology to deliver water at high pressures. The trailer is utilized as a water tanker and holds 2,000 liters of water. The trailer is equipped with a centrifugal pump, a boiler, and pipelines. The pump is capable of suctioning water from reservoirs to a height of 5 m. Using the boiler, the trailer can heat up the entire 2,000-liter water supply to 60 °C in 60 to 80 minutes.[1] The FMU is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.54.4 Truck-Mounted Universal Decontamination Equipment FMG-90.

The FMG-90 is designed for the decontamination of exterior equipment, personal equipment, and fixed sites (i.e. terrain). The unit delivers decontamination solutions with high-pressure. Depending on which decontamination solutions is utilized the FMG-90, shown in Figure 6.54.4, may employ chemical or mechanical technology. The FMG-90 is used to mix decontamination solutions, wash down surfaces, heat decon solutions, and pump water. The body of the FMG-90 is comprised of a pump unit that is carried on a 6x6 vehicle. The FMG-90 is equipped with a pressure centrifugal pump, a high-pressure pulsating pump, a 5,000-liter water tank, a decontaminant mixer, a heater and boiler, and pipelines. The pumps can raise water 5 m high.

The unit can be operated in either a low or high-pressure mode. In the low-pressure mode, the system can supply water/decontaminant mixtures to 40 workstations as far as 90 m away at a flow rate of 13 liters per hour. Running in a high-pressure mode, the FMG-90 can only supply water/decontaminant mixtures to 8 work stations as far as 300 m away at a flow rate of 220 liters per minute. Depending on the initial temperature, the system can heat the 5,000-liter water supply to 70°C in 60 to 90 minutes.[1] The FMG-90 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

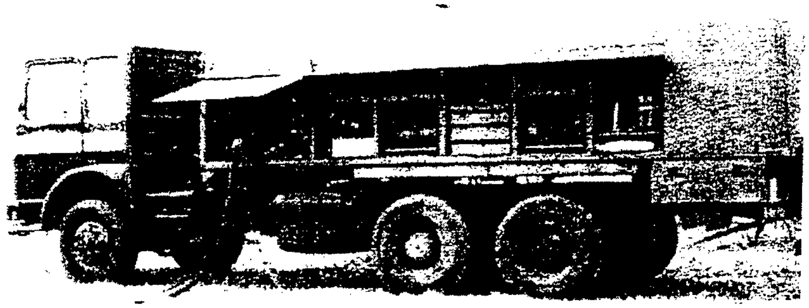


Figure 6.54.4. The FMG-90 is used to mix decontamination solutions, wash down surfaces, heat decon solutions, and pump water. Photo reproduced with permission from Jane's Information Group.

6.54.5 Individual Decontamination Kits.[1]

The FVCS-78, FVCS-M, and the FVS are manufactured by TECHNIKA Foreign Trade Company and are in service with the Hungarian armed forces. The three kits employ chemical technology and utilize decontaminants in an aqueous solution for decontamination. The FVCS-78 Individual Decontamination Packet is designed to decontaminate a single soldier's personal equipment and small arms. The kit consists of a plastic bag containing calcium hypochlorite powder that is filled with water to produce the decontamination solution.

The FVCS-M Decontamination Kit is designed to decontaminate weapons. A rubber coated polyethylene bag sealed inside a linen bag contains 120 grams of calcium hypochlorite, 5 grams of an emulsifier, and 6 grams of activated aluminum foil. The three components are added to 0.5 liters to 0.7 liters of water which warms to 60°C to 70°C within 10 minutes. The decontamination solution is applied using a soft cloth (not included).

The FVS Individual Decontamination Spray is designed to decontaminate equipment, including sensitive optical and electronic equipment. A plastic bottle contains UDL decontamination solution and a spray head.

The FVCS-78, FVCS-M, and the FVS are intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	✓
Interior Equipment Decon	
Large Area Decon	

6.54.6 Field Shower Unit FF.

The FF Field Shower Unit is designed for the decontamination of personnel. The Field Shower Unit employs mechanical technology and disseminates a high-pressure spray of water. The unit includes four shower frames, each containing six showerheads and one 40 mm threaded outlet. The unit is also supplied with eight rubber drainage mats (7 m x 120 mm x 3 mm) and four tents, two for the shower area and two for the dressing and undressing area. The showers can hold up to 48 personnel with a recommended shower time of 10 minutes providing each person with 15 liters of water. The shower is intended to decontaminate 250 to 280 personnel per hour.[1] The FF Field Shower Unit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

6.55 Texas Research Institute Austin, Inc. – UNITED STATES.

6.55.1 Decon-Check.

The Decon-Check Kit, shown in Figure 6.55.1, is designed to remove surface contaminants (no chemical warfare agents listed) from clothing. The Decon-Check Kit is manufactured by Texas Research Institute Austin, Inc. The kit employs both mechanical and chemical technologies to deliver a high-pressure spray of detergents, emulsifiers, and surfactants to remove surface contaminants. The Decon-Check Kit includes an air powered sprayer with a 25 foot air hose (compressed air not included), a brush head, four 2.2 liter bottles of Decon-Check solution, an adjustable extension handle (2-4 feet) with a control valve, and a duffel bag for storage and transit. Storage temperatures range from 40.5°F to 110°F. The Decon-Check Kit may offer potential for supporting the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.55.1. The Decon-Check Kit delivers a high-pressure spray of detergents, emulsifiers, and surfactants to remove surface contaminants. Photos courtesy of Texas Research Institute Austin, Inc.

6.56 Tirrene SpA. – ITALY.

6.56.1 <u>Tirrena Small Decontamination Set, SDS T155</u>.

The SDS T155 Tirrena Small Decontamination Set, shown in Figure 6.56.1, is designed for the immediate decontamination of vehicles and equipment. The SDS T155 is manufactured by Tirrena SpA of Italy and is in service with the Italian Army. The system employs chemical technology and delivers a high-pressure spray of DS2.

The SDS T155 is a small fire-extinguisher-type refillable dispenser, propelling DS2 by compressed nitrogen. The compressed nitrogen is supplied from a loading container 40 mm in diameter, which weighs 300 grams. The compressed nitrogen is pressurized to 20 kg/cm^2 (the fire-extinguisher dispenser is tested to 55 kg/cm^2) and has a maximum capacity of 1.85 liters (normal operating capacity of 1.5 liters). A single dispenser can decontaminate 6 m^2 to 8 m^2 from a 2 m distance. The dispenser is 125 mm in diameter, 310 mm high and weighs 4.3 kg full (2.8 kg empty).[1] The SDS T155 Tirrena Small Decontamination Set is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.56.1. The SDS T155 Tirrena Small Decontamination Set is a small fire-extinguisher-type refillable dispenser, propelling DS2 by compressed nitrogen. Photo reproduced with permission from Jane's Information Group.

6.57 Tovama Avtomobilov Motorjev – SLOVENIA.

6.57.1 NBC Decontamination Vehicle.

The NBC Decontamination Vehicle, shown in Figure 6.57.1, is designed for general decontamination. The vehicle is manufactured by Tovama Avtomobilov Motorjev of Slovenia and is in service with the Yugoslav armed forces. The NBC Decontamination vehicle is equipped with a decontamination spray and depending on which decontaminant is utilized, the system may employ chemical and/or mechanical technologies via an independently powered pump unit. The system is vehicle mounted on a TAM 150 T11 BV (3,000 kg /5,000 kg truck) and carries a decontamination solution tank over the rear axle.[1] The NBC Decontamination Vehicle is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

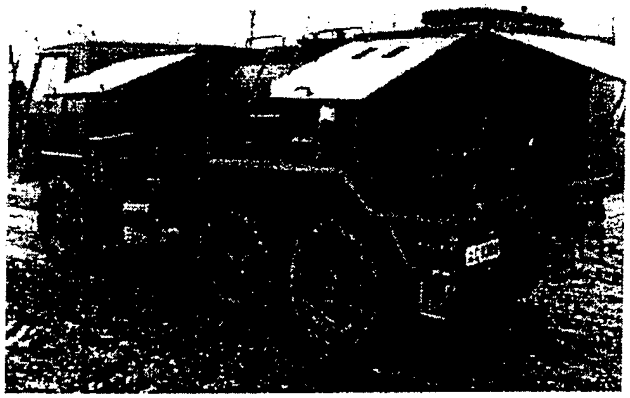


Figure 6.57.1. The NBC Decontamination Vehicle, manufactured by Tovama Avtomobilov Motorjev of Slovenia, is designed for general decontamination. Photo reproduced with permission from Jane's Information Group.

6.58 Tradeways Limited – UNITED STATES.

6.58.1 Decontaminating Apparatus, ABC-M12A1.

The ABC-M12A1 Decontaminating Apparatus, shown in Figure 6.58.1, is designed for the decontamination of vehicles and personnel. The ABC-M12A1 is manufactured by All-Bann Enterprises Inc., marketed by Tradeways Limited, and is in service with the U.S. armed forces. The apparatus employs chemical (primary) and mechanical (secondary) technologies. The system delivers a high-pressure spray decontaminating solution, Super Tropical Bleach (STB), but other decontamination solutions may be used.

The apparatus includes a stainless steel decontaminant tank and a hopper-mixer as well as a shower assembly for 25 personnel. For transport, the units are placed in three crates with a combined weight of 1,903 kg.[1] It is capable of providing heated water at a rate of 2,270 liters/hour. The pump unit includes two hoses and is capable of delivering 190 liters/minute of decontaminating agent. The ABC-M12A1 is used in conjunction with the Vehicle-Mounted Decontamination Apparatus (VMDA) produced by Brunswick Defense. The combined system can function with a vehicle wash frame or a troop shower. A five ton truck carries the VMDA, fuel, and decontamination materials. The ABC-M12A1 Decontaminating Apparatus is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

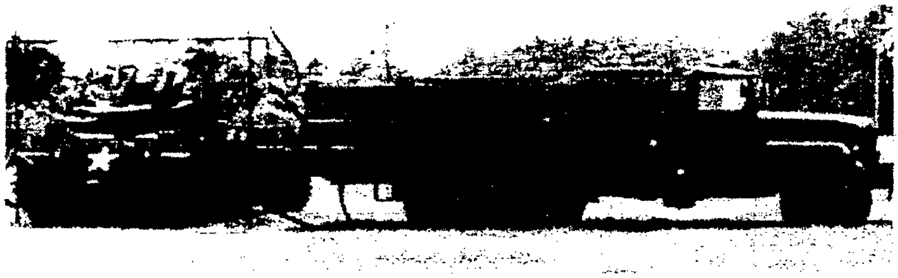


Figure 6.58.1. The ABC-M12A1 Decontaminating Apparatus system delivers a high-pressure spray of decontaminating solution. Photo reproduced with permission from Jane's Information Group.

6.58.2 Decontamination Kit No. 2.

The Decontamination Kit No. 2 is used to decontaminate personal equipment and can be used in conjunction with the M281 Skin Decontamination Kit for emergency decontamination. The kit, shown in Figure 6.58.2, is marketed by Tradeways Limited and marketed by Tradeways Limited of Maryland. The Decontamination Kit No. 2 employs sorbent technology and utilizes a 15 g squeeze bottle to dispense AMBERGARD™ XE-555 decontaminant. The kit is able to decontaminate all known liquid chemical agents. The kit can decontaminate 6,900 cm^2 at a challenge level of 2.5 g/m^2. The Kit is 95 mm x 55 mm x 25 mm high and has a recommended storage temperature from -51°C to +71°C.[1] The Decontamination Kit No. 2 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

Figure 6.58.2. The Decontamination Kit No. 2 uses a 15g squeeze bottle to dispense AMBERGARD™ XE-555 decontaminant. Photo reproduced with permission from Jane's Information Group.

6.58.3 <u>M291 Skin Decontamination Kit (SDK)</u>.

The M291 Skin Decontamination Kit is used to decontaminate the skin and in an emergency situation to decontaminate the exterior of protective masks, butyl rubber gloves, hoods, and individual weapons. The SDK is marketed by Tradeways Limited of Maryland, and is in service with the U.S. Armed Forces. The SDK, shown in Figure 6.58.3, employs both sorbent and chemical technologies. The kit utilizes a non-woven pad impregnated with a decontamination compound. The 45 gram SDK replaces the M258A1, and is 112 mm square by 36 mm high.[1] The M291 Skin Decontamination Kit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

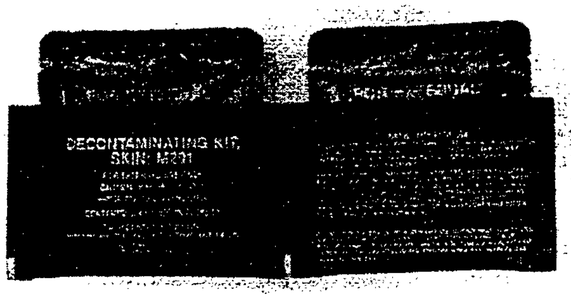


Figure 6.58.3. The M291 Skin Decontamination Kit is used to decontaminate the skin and in emergency situation to decontaminate the exterior of protective masks, butyl rubber gloves, hoods, and individual weapons. Photo reproduced with permission from Jane's Information Group.

6.58.4 <u>Decontamination Kit, Individual Equipment M295</u>.

The M295 Individual Equipment Decontamination Kit is used to decontaminate protective hoods, masks, gloves, footwear, personal weapons, helmets, and webbing. The M295 Kit, shown in Figure 6.58.4, is manufactured by Trutech, marketed by Tradeways Limited of Maryland, and is in service with the U.S. armed forces. The M295 Kit employs sorbent technology and utilizes AMBERGARD™ XE-555 (decontaminant) in four wipedown mitts that are made of non-woven polyester material with a polyethylene film backing. Twenty kits are to be supplied, in one container for squad or section use. Each kit weighs 227 grams and is 220 mm x 140 mm x 50 mm high and has an operating temperature range from -32°C to +71°C.[1] The M295 Individual Equipment Decontamination Kit is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

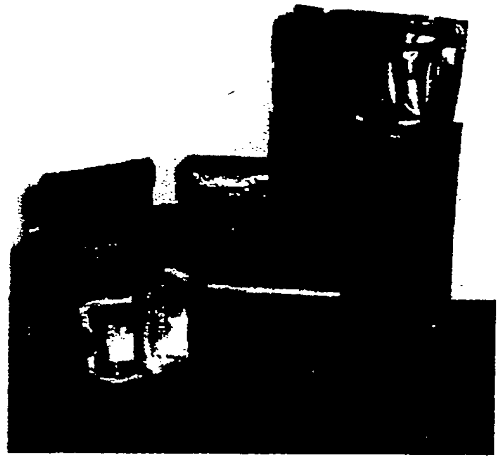


Figure 6.58.4. The M295 Individual Equipment Decontamination Kit is used to decontaminate protective hoods, masks, gloves, footwear, personal weapons, helmets, and webbing. Photo courtesy of Sgt. Michael O'Hern - Retired, U.S. Army.

6.59 Vapormatt Inc – UNITED STATES.

6.59.1 Vapormate.

The Vapormate, shown in Figure 6.59.1, is an advanced cleaning system designed to clean interior and exterior equipment. The Vapormate is commercially available in the U.S. and is manufactured by Vapormatt. The system employs mechanical technology and delivers a unique high-pressure spray, which is comprised of a mixture of water and a range of abrasives (i.e. glass beads, silicone carbide, ceramic and plastic abrasives) to simultaneously degrease and surface clean all metal and plastic components. The system is equipped with a blast gun to control the spray. The Vapormate could potentially be used to decontaminate equipment, which have been contaminated by chemical agents. The system is 27.5 inches long, 27.5 inches wide, and 49 inches high. The Vapormate may offer potential for supporting the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	✓
Large Area Decon	

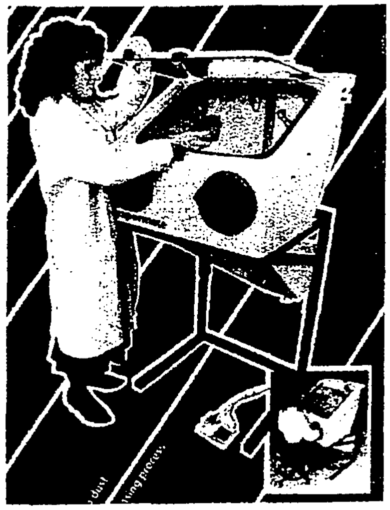


Figure 6.59.1. The Vapormatt Vapormate is an advanced commercial cleaning system designed to clean interior and exterior equipment.

6.59.2 Vapormaster 1315.

The Vapormaster 1315 is an advanced cleaning system similar to the Vapormate. The system is designed to clean interior and exterior equipment. The Vapormaster 1315, shown in Figure 6.59.2, is commercially available in the U.S. and is manufactured by Vapormatt. The system employs mechanical technology and delivers a unique high-pressure spray, which is comprised of a mixture of water and a range of abrasives (i.e. glass beads, silicone carbide, ceramic and plastic abrasives) to simultaneously degrease and surface clean all metal and plastic components. The system is equipped with a blast gun to control the spray, which dispenses the air/abrasive mixture at a rate of 40 scfm at 80 psi. The Vapormaster 1315 could potentially be used to decontaminate equipment that has been contaminated by chemical agents. The system is 51 inches long, 53 inches wide, and 87 inches high. The Vapormaster 1315 may offer potential for supporting the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	✓
Large Area Decon	✓

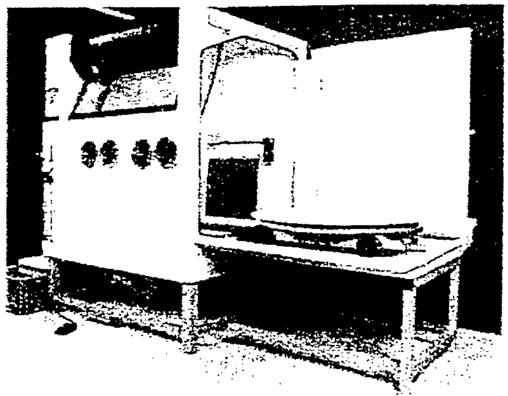


Figure 6.59.2. The Vapormatt Vapormaster 1315 is an advanced cleaning system similar to the Vapormate.

6.60 Va-Tran Systems, Inc. – UNITED STATES.

6.60.1 Sno Gun (SG-1).

The Sno Gun SG-1, shown in Figure 6.60.1, is a hand held device designed to remove contaminants as small as 0.1 micron from sensitive equipment. The SG-1 is commercially available in the US and is manufactured by Va-Tran, Inc. The device employs mechanical technology (high-pressure CO_2) to remove contamination from the surfaces of electronics, optics, disk drives, semiconductors, and other micro-mechanical assemblies without damaging the part. The contaminants are carried away in a stream of inert CO_2. The Sno Gun SG-1 may offer potential for supporting the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	
Large Area Decon	

Figure 6.60.1. The VA-Tran Systems Sno Gun SG-1 is hand held device designed to remove contaminants as small as 0.1 micron from sensitive equipment. Photo courtesy of VA-Tran Systems.

6.60.2 Supersonic Gas/Liquid Cleaning System (SS-GLCS).

The SS-GLCS, shown in Figure 6.60.2, is a cleaning system designed to remove oil and grease from sensitive equipment. The system is commercially available in the U.S. and is manufactured by Va-Tran Systems Inc. The SS-GLCS employs mechanical technology. A water mist spray is injected into a supersonic stream of air. The air and water mix and the mixture is ejected at supersonic speeds from a single nozzle or a series of nozzles at the end of a hand held wand. The SS-GLCS is used to clean optics, plastics, electronics, and circuit boards. NASA is currently using the SS-GLCS to replace CFC-based solvents. Test results have shown that oil and grease can be removed at a 95% efficiency rating. The SS-GLCS requires 115 VAC at 60 Hz and weighs 450 pounds. The SS-GLCS may offer potential for supporting the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	

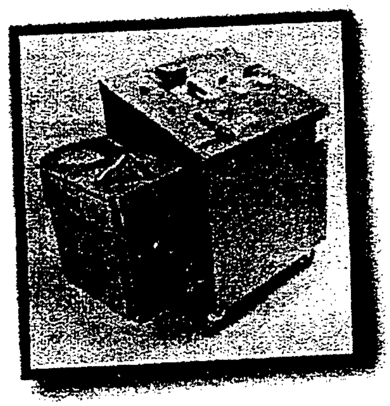


Figure 6.60.2. The Va-Tran Systems SS-GLCS is a cleaning system designed to remove oil and grease from optics, plastics, electronics, and circuit boards.

6.60.3 Micro Precision Steam Cleaner (MPS-1).

Micro Precision Steam Cleaner, shown in Figure 6.60.3, is a portable steam cleaner designed to clean sensitive equipment. The unit is commercially available in the U.S. and is manufactured by Va-Tran Systems, Inc. The MPS-1 employs mechanical technology and delivers high-pressure super-heated steam to effectively remove grease, oil, flux, adhesive, fingerprints, and many other contaminants from circuit boards, optics, and other electronics. The MPS-1 is equipped with a cabinet, exhaust fans, spotlights, a cart, and three separate interchangeable nozzles. One nozzle is used to dispense a single jet of steam, another nozzle disperses a flat spray, and the third nozzle is used to clean holes and tubes. The super-heated steam is kept at a temperature of 500°F, at a pressure of 150 psi and requires 115 VAC at 9 amps. The MPS-1 weighs 18 pounds and is 7.5 inches wide, 11 inches deep, and 8 inches high.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	

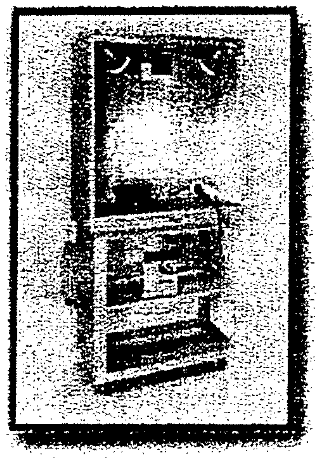


Figure 6.60.3. The Va-Tran Systems MPS-1 is a cleaning system designed to remove oil and grease from optics, plastics, electronics, and circuit boards.

6.61 Ventilatorverken - SWEDEN.

6.61.1 Hot Air Unit VA-8.

The VA-8 is hot air generating unit, shown in Figure 6.61.1, that is designed for the decontamination of personal equipment. The system is manufactured in Sweden by Ventilatorverken and is currently in production. The unit employs low-temperature thermal technology to decontaminate uniforms and other equipment. The unit can heat air to temperatures between 110°C to 130 °C, however, hot air can be produced to a maximum temperature of 220 °C. The unit can produce a flow rate between 800 to 1,000 m^3 per hour and is capable of decontaminating 75 uniforms per hour. The hot air is generated using a pulse jet motor, which works by combining exhaust air with fresh air and then blowing the mixture into the decontamination chamber. The unit weighs 140 kg and is 2.06 m long, 603 mm wide, and 660 mm high.[1] The Hot Air Unit VA-8 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

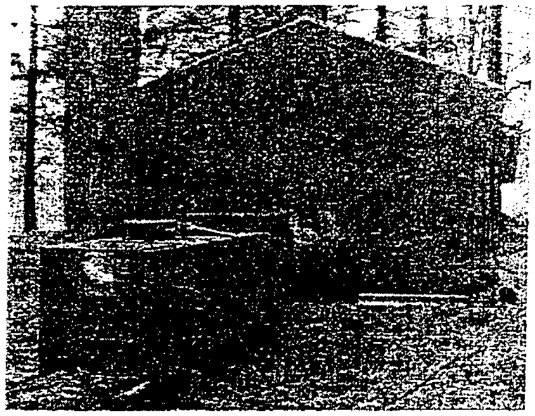


Figure 6.61.1. The VA-8 is hot air generating unit that is designed for the decontamination of personal equipment. Photo reproduced with permission from Jane's Information Group.

6.62 VOP 025 Novy Jicin, SP – CZECH REPUBLIC.

6.62.1 <u>ACHR-90 NBC Decontamination Vehicle.</u>

The ACHR-90 is a vehicle used for the decontamination of sensitive and exterior equipment, skin and personal equipment, and fixed sites. The vehicle, shown in Figure 6.62.1, is manufactured in the Czech Republic by VOP and is currently in prototype development. The vehicle employs both chemical (primary) and mechanical (secondary) technologies. The system disperses water and decontaminant mixtures onto contaminated terrain and equipment at high-pressures. The ACHR-90 is equipped with a 6,000-liter water tank, two 2,000 liter rubber tanks, decontamination wands, piping, hoses, nozzles, a personnel shower system, mixers, and a generator. The 6,000-liter tank is split into 3 chambers. One chamber is filled with water, while the other 2 chambers are filled with decontamination solutions.

The vehicle can be used in conjunction with the Cristianini SANIJET C921. Working together, the system can disperse approximately 100 liters per hour of decontaminant solution, warm water, or cold water, at a pressure of 4.5mPA. The system has an operating range of 1,000 km. The ACHR-90 is also capable of decontaminating terrain and road over a 12 m width as well as supplying warm water to personnel showers. The vehicle weighs 22 tons and is 8.7 m long, 2.5 m wide, and 3.32 m wide.[1] The ACHR-90 NBC Decontamination Vehicle is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	✓

Figure 6.62.1. The ACHR-90 is a vehicle used for the decontamination of sensitive and exterior equipment, skin and personal equipment, and fixed sites.

6.62.2 The APZ-94 Ecological Vehicle

The APZ-94, shown in figure 6.62.2, is a quick response vehicle designed to assist in the clean up of ecological disasters. It is manufactured by Novy Jicin and is commercially available in the Czech Republic. The system employs mechanical technology and is designed to decontaminate exterior equipment and large area. The low-pressure system, in conjunction with a META pump, allows for fire extinguishing and the spraying of mixtures to include road and terrain washing while the vehicle is in motion. The maximum width of terrain spraying is approximately 12 m. The high-pressure system is utilizes two SANIJET units. The units are capable of producing steam for decontamination purposes or can be used for heating individual tank chambers. With the vehicle fittings, the system is capable of pumping highly aggressive agents at a maximum rate of 140 liters/min. or it can be used to create an individual workstation allowing special cleaning with the liquid stored in tank chambers.

The vehicle cabin accommodates a four-member crew and is equipped with a variety of accessories (light and sonic warning equipment, equipment for primary detection, databank of dangerous substances, etc). Also, the vehicle can be modified to meet additional user requirements. The APZ-94 Ecological Vehicle weighs 17,000 kg and is 870 cm long, 250 cm wide and 332 cm high. The APZ-94 is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

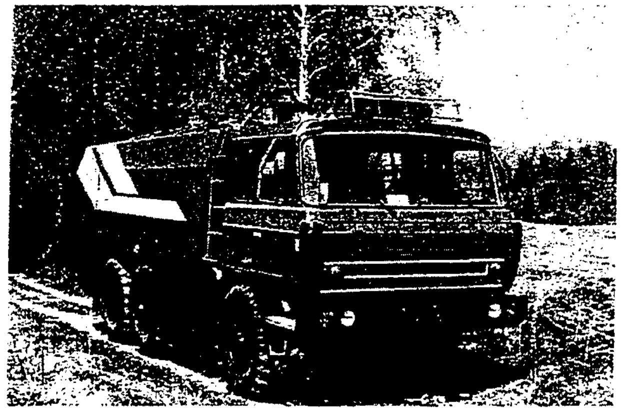


Figure 6.62.2. The APZ-94 is designed to decontaminate exterior equipment and large areas using pressurized washing. Photo courtesy of Novy Jicin.

6.63 Western Emergency Equipment – UNITED STATES.

6.63.1 Washing Equipment.

Western Emergency Equipment manufactures a complete line of emergency eyewashes, drench showers, tempered water systems, portable models and accessories, which are commercially available in the US. The systems, shown in Figure 6.63.1, are designed to decontaminate skin and personal equipment. Western Emergency Equipment systems employ mechanical technology to deliver high-pressure sprays of water. The equipment is manufactured in a wide variety of shapes and sizes. The Washing Equipment may offer potential for supporting the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

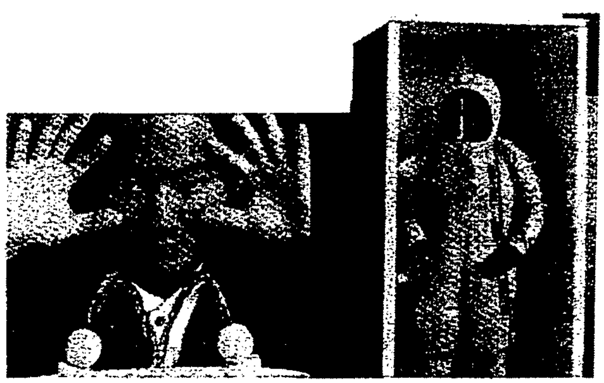


Figure 6.63.1. Western Emergency Equipment line of emergency eyewashes, drench showers, tempered water systems, portable models and accessories. Photos courtesy of Western Emergency Equipment.

6.64 Wojskowe Zaklady Lotnicze NR 2 – POLAND.

6.64.1 WUS-3 Truck-Mounted Vehicle Decontamination Apparatus.

The WUS-3, shown in Figure 6.64.1, is a truck-mounted apparatus designed to decontaminate vehicles, exterior equipment, and large areas. The system is manufactured in Poland by Wojskowe Zaklady Lotnicze and is in service with the Polish armed forces. The WUS-3 employs both chemical (primary) and mechanical (secondary) technologies. The system utilizes a SO-3 jet turbine engine to spray decontaminants over contaminated vehicles, roads, and runways. The engine can be transversed left and right at right angles. The engine can also be elevated 15° and depressed 25°. The system is operated from a control center located on the right-hand side of the roof of the vehicle on which it is mounted.[1] The WUS-3 Truck-mounted Vehicle Decontamination Apparatus is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

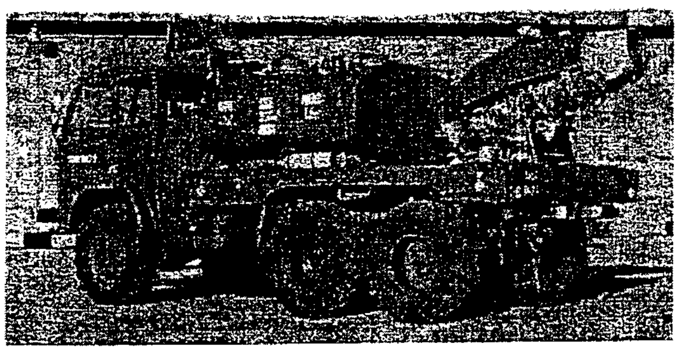


Figure 6.64.1. The WUS-3 uses a SO-3 jet turbine engine to spray decontaminants over contaminated vehicles, roads, and runways. Photo reproduced with permission from Jane's Information Group.

6.65 Zenon Environmental Systems Inc.

6.65.1 Zenon Advanced Double Pass Reverse Osmosis Water Purification Unit (ADROWPU)

The ADROWPU is designed to purify water that has been contaminated with NBC agents. The unit is manufactured by Zenon Environmental Systems, Inc. and is currently in service with Canadian and Taiwanese armies. The ADROWPU utilizes a double pass reverse osmosis process in order to remove contamination. The process is employs pressure to separate dissolved solutes and suspended substances from water.

The system, show in Figure 6.65.1, is equipped with a 40 kW diesel power generator and a self-cleaning system. The unit weighs 6,400 kg and is 5.5 meters long, 2.1 meters wide, and 1.7 meters high. The basic ADROWPU can purify 84,700 liters/day of fresh water, 58, 950 liters/day of brackish water, and 52,390 liters/day of seawater. The system can be operated at –40 to +40°C.[1] The ADROWPU is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area	✓

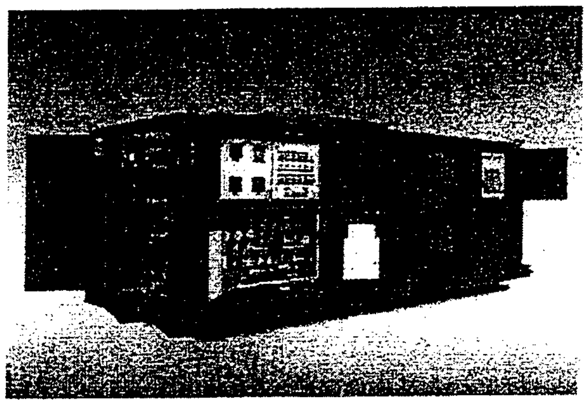


Figure 6.65.1. The ADROWPU employs reverse osmosis in order to purify water that has been contaminated with NBC agents. Photo reproduced with permission from Jane's Information Group.

7.0 CB Decontamination Programs

This section identifies and provides a brief overview of Government funded CB Decontamination Programs currently in Production, under Engineering Development (6.3 – 6.5), or being evaluated in Tech Base (6.2). The section also identifies Engineering Development or Tech Base Programs terminated prior to Production. Items that have been fielded are not discussed in this section, but are contained under CB Decontamination Equipment (Section 6.0). Attempts were made to identify International Tech Base, Engineering Development, and Production Programs related to CB Decontamination. Unfortunately, a limited amount of information has been received at this time and efforts are ongoing to acquire additional information for incorporation into the next submission of this report.

7.1 Current U.S. Production Programs

7.1.1 M17 Lightweight Decontamination System (LDS)

7.1.1.1 Sponsor. DoD, U.S. Army. Point of Contact: Mr. James Bina, Production Manager, Rock Island Arsenal, Rock Island IL, (309) 782-0738.

7.1.1.2 Program Description. The M17 Lightweight Decontamination System (LDS) is used to decontaminate equipment, personnel and other material exposed to CB contaminants. The M17 LDS is a lightweight, portable decontaminating apparatus. It consists of an air-cooled two-cycle gasoline powered engine, heat exchanger, and water pump. A 1580 or 3000 gallon collapsible water tank is provided. The M17 LDS is currently in production at Rock Island Arsenal. Production of 638 M17 LDS was reinitiated for FY98-00 based on the results of the findings contained in the Quadrennial Defense Review (QDR). FY98 funding was provided as a direct congressional plus-up.

7.1.1.3 Functional Areas. The M17 LDS may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

7.2 Current U.S. Engineering Development Programs

7.2.1 M21/M22 Modular Decontamination System (MDS)

7.2.1.1 Sponsor. DoD, U.S. Army. Point of Contact: Mr. Rinaldo Bucci, Team Leader, U.S. Army ECBC, APG-EA MD, (410) 436-5526.

7.2.1.2 Program Description. The Modular Decontamination System (MDS) is being developed to provide the soldier an improved capability to perform detailed equipment decontamination on the battlefield. The MDS consists of the M21Decontaminant Pumper/Scrubber module and a M22 High Pressure/Hot Water module to deliver DS2 or liquid field-expedient decontaminants up to 3000 psi at a rate of 5 gpm. The MDS is currently scheduled to complete RDT&E in FY98 with Initial Production in FY99. A 5-year production program is planned to produce and field approximately 600 MDSs. The proposed Basis of Issue (BOI) for fielding is based on providing 3 MDSs per decontamination platoon to replace the 3 M12A1 PDDA currently in each platoon. Fielding to U.S. Naval facilities decontamination units is also envisioned but as of yet undefined.

7.2.1.3 Functional Areas. The M21/M22 MDS may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

7.2.2 Sorbent Decontamination

7.2.2.1 Sponsor. DoD, U.S. Army. Point of Contact: Ms. Gyleen Fitzgerald, Team Leader, U.S. Army ECBC, APG-EA MD, (410) 436-5592.

7.2.2.2 Program Description. Sorbent Decontamination is being developed to provide a simple, rapid, and efficient system to decontaminate small and individual issue items of equipment. This program will replace the use of DS2 from immediate (Basic Soldier Skills) decontamination through the use of a catalytic component that reacts with the chemical agents being sorbed. The new sorbent is proposed to replace the current XE555 decontaminate resin contained within the M295 Decontamination Kit. In addition, Sorbent Decontamination will replace the M11 and M13 Decontamination Apparatus. RDT&E efforts are scheduled to be completed in FY01. Procurement of the item will be customer funded and is scheduled for initiation in FY02 with sorbent replacement in the M295 Decontamination Kit and M11/13 DAPs occurring in FY03 and FY05, respectively. No specific production quantities have been established at this time.

7.2.2.3 Functional Areas. Sorbent Decontamination may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

7.2.3 Joint Service Fixed Site Decontamination (JSFXD) – Block I

7.2.3.1 Sponsor. DoD, U.S. Marine Corps. Point of Contact: MSgt Vic Murphy, Program Manager, MarSysCom, Quantico, VA, DSN 278-2912 x22.

7.2.3.2 Program Description. The JSFXD is a new program starting in FY99. It will address the requirement to decontaminate large areas, ports of entry, airfields, logistic support bases, and key command and control centers which have been exposed to the damaging effects of NBC agents/ contaminants and toxic industrial materials (TIMs). The JSFXD will incorporate both a family of decontaminants and a family of decontamination application systems to enhance force protection through personnel, equipment, facility, and area decontamination. It is expected that the JSFXD will encompass currently developed and fielded decontamination solutions and equipment as well as on-going developmental technology base and engineering efforts to address nerve and mustard agent contamination. A Block II effort is envisioned to transfer into the Engineering Development Program in FY01 but is currently unfunded. The Block II effort would focus on identifying potential decontamination applications. This program received funds in FY98 that was used to initiate various studies and tests, some of which are described in the following paragraphs. The results of these efforts will form the foundation for the program when it starts in FY99.

7.2.3.3 Functional Areas. JSFXD – Block 1 may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	✓

7.2.4 JSFXD – Block I: Joint Service CB Decontaminants Study

7.2.4.1 Sponsor. DoD, Joint Service Program, U.S. Army Lead Agency. Point of Contact: Dr. John Weimaster, R&T Decontamination Business Area Manager, U.S. Army ECBC, APG-EA MD, (410) 436-4148.

7.2.4.2 Program Description. The CB Decontaminants research study is being conducted in support of the JSFXD – Block I Program. The study is focused on testing and evaluating possible non development item (NDI) decontaminants and equipment systems that may serve as short term replacements for DS2. Its current focus has been on the evaluation of the Italian decontaminant BX-24. In FY98, laboratory studies were proposed to assess reaction products and kinetics and to conduct laboratory coupon studies. Test efforts included the conduct of decontamination chamber tests of large panels contaminated with live chemical agents at the U.S. Army Dugway Proving Ground (DPG). Field testing and evaluation of decontamination equipment using simulants were also conducted in conjunction with the MDS test.

7.2.4.3 Functional Areas. The results of the CB Decontaminants research study support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

7.2.5 JSFXD – Block I: Biological Warfare Agent Decontamination Reaerosolization Study

7.2.5.1 Sponsor. DoD, Joint Service Material Group (JSMG). Point of Contact: MAJ Joseph Kiple, Decontamination Commodity Area Manager, JSMG, APG-EA MD, (410) 436-8489.

7.2.5.2 Program Description. The Biological Warfare Agent Decontamination Reaerosolization Study is being conducted in support of the JSFXD – Block I Program. The objective of this study is to determine the hazard posed by the reaerosolization of biological agents. A field test was conducted at the U.S. Army Dugway Proving Ground in August 1998 to acquire the necessary data to draw conclusions to the stated study objective. Data assessment is currently ongoing.

7.2.5.3 Functional Areas. The results of the Biological Warfare Agent Decontamination Reaerosolization Study support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	✓

7.2.6 Development of Filtration and Decontamination Equipment Using Biocide Technology

7.2.6.1 Sponsor. DoD, U.S. Army. Points of Contact: COL Platoff, Army U.S. Army Medical Research Materiel Command, (301) 619-7888, and Mr. William Argiropoulos, Decontamination Core Team Leader, U.S. Army ECBC, Engineering Directorate, (410) 436-5680.

7.2.6.2 Program Description. The Biocide Program is a Congressionally funded program investigating the development of Triosyn® technologies for use in CB defense and medical applications. This resin is a special application polymer developed by Hydro Biotech Inc. that collects biological agents and incorporates I^- and I_2 release to destroy biological agents as well as other biohazards. It has been successfully used in commercial water filter applications and has undergone limited testing in dry applications. Using the Triosyn® resin, permeable barrier material applications are being developed.

7.2.6.3 Functional Areas. The Biocide technology developments may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	✓
Large Area Decon	✓

7.3 Current U.S. Tech Base Programs and Studies with Future/Planned U.S. Projects

7.3.1 Superior Decontamination Solution

7.3.1.1 Sponsor. DoD

7.3.1.2 Program Description. The Superior Decontamination Solution Program consists of a series of Tech Base projects aimed at replacing DS2 and other decontaminating solutions. As these projects mature, they will be transitioned to the Joint Service Fixed Site Decontamination Program. Currently, these projects include oxidative and nucleophilic substitution processes, enzymes, quaternary ammonium complexes, surfactant-based oxidation systems, mixed aqueous/organic solvent systems, and monoethanol amine reactant. The decontamination Tech Base Programs that comprise this effort are detailed in the following paragraphs. The funding for the Engineering Development Program was cut through FY05 to provide funding for programs in procurement; however funding may be provided in future POM cycles.

7.3.1.3 Functional Areas. The Superior Decontamination Solution Program may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	✓
Large Area Decon	✓

7.3.2 Superior Decontamination Solution: BW Decontamination Efficacy Evaluation

7.3.2.1 Sponsor. DoD, U.S. Army. Point of Contact: Mr. Abe Turetsky, U.S. Army ECBC R&T Directorate, APG-EA MD, (410) 436-2404.

7.3.2.2 Program Description. The objective of the BW Decontamination Efficacy Evaluation is to initiate biological agent decontamination efforts through the evaluation of currently fielded NATO chemical agent decontaminants and experimental chemical agent decontaminants. Accomplishments to date include the demonstration of the activity of 7 chemical agent decontaminants (DS2, DS2P, GD5, STB, BX24, C8 and CAD) toward vegetative forms of *B. anthracis* and *Yersinia* strains and the sporicidal activity of decontaminant GD5. Future studies include the quantification of the biological agent decontamination activity of chemical agent decontaminants on military significant substrates.

7.3.2.3 Functional Areas. The results of the BW Decontamination Efficacy Evaluation efforts support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	✓
Large Area Decon	✓

7.3.3 Superior Decontamination Solution: Surfactant-Based Decontamination Solution Study

7.3.3.1 Sponsor. DoD, U.S. Naval Systems Warfare Center (NSWC), Chemical/Biological Systems Analysis Branch. Point of Contact: Mr. Jerry Brown, U.S. NSWC, (540) 653-8162.

7.3.3.2 Program Description. The objective of the Surfactant-Based Decontamination Solution Study is to develop a surfactant-based decontamination solution that will solubilize agents and be non-corrosive, non-toxic and environmentally "Green". Oxidation study efforts include the evaluation and selection of oxidizers that are compatible with the surfactant solution and effectively oxidize chemical agents and chemical agent simulants. Surfactant study efforts include the formulation of an emulsion system that is stable to oxidation and hydrolysis and will solubilize chemical agents and chemical agent simulants. International cooperative efforts in this area are on-going with Dr. Holmberg, Institute for Surface Chemistry (ISC), Stockholm (microemulsion formulation) and with Dr. Degussa, Frankfurt (peroxy acid chemistry/HD simulant). Upcoming study efforts include a detox efficiency evaluation of the surfactant-based decontamination solution against military surfaces (coupons) contaminated with live agent and a reaction products evaluation focused on identifying the reaction products and the validation that no toxic by-products exist.

7.3.3.3 Functional Areas. The results of the Surfactant-Based Decontamination Solution Study support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	✓
Large Area Decon	✓

7.3.4 Superior Decontamination Solution: Quaternary Ammonium Complex Decontaminant Study

7.3.4.1 Sponsor. DoD, U.S. Naval Systems Warfare Center (NSWC). Point of Contact: Dr. Donald T. Cronce, U.S. NSWC.

7.3.4.2 Program Description. The objective of the Quaternary Ammonium Complex Decontaminant Study is to evaluate the formulation of a new multi-agent decontamination solution that is both noncorrosive and nontoxic. The current formulation of the new solution consists of quaternary ammonium complexes (20% w/w), 2-amino-2methyl-1-propanol (30% w/w), aqueous solution/water (30%w/w) and peroxide oxidizer (20% w/w). The study efforts include the proof of concept against HD, GD, and VX and the identification of reaction products. Material compatibility, stability, and surface evaluation studies have also been performed. Remaining technical challenges primarily include the improvement of reactivity and solubility towards HD and the decrease of the reaction half-life.

7.3.4.3 Functional Areas. The results of the Quaternary Ammonium Complex Decontaminant Study support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	✓
Large Area Decon	✓

7.3.5 Superior Decontamination Solution: DS2 Replacement Study

7.3.5.1 Sponsor. DoD, U.S. Army. Point of Contact: Mr. Philip W. Bartram. U.S. Army ECBC R&T Directorate, APG-EA MD, (410) 436-4426.

7.3.5.2 Program Description. The objective of the DS2 Replacement Study is to evaluate and optimize a decontaminant based on sulfolanes, water and calcium hypochlorite that is environmentally "Green", and non-toxic. Study efforts to date have determined the solubility of HD, GD, and VX in mixtures of sulfolanes and water and have determined the decontamination efficacy of sulfolanes, water, and calcium hypochlorite against THD, VX, and TGD on CARCs. Remaining technological barriers to be achieved include the formulation of a water/calcium hypochlorite solution for use in extreme cold conditions, the limited material compatibility of hypochlorite based decontaminants, and the halt in production of 3-methyl sulfolane by industry.

7.3.5.3 Functional Areas. The results of the DS2 Replacement Study support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	✓
Large Area Decon	✓

7.3.6 Superior Decontamination Solution: Enzymatic Decontamination Study

7.3.6.1 Sponsor. DoD, U.S. Army. Point of Contact: Dr. Joseph J. DeFrank, U.S. Army ECBC R&T Directorate, APG-EA MD, (410) 436-3749.

7.3.6.2 Program Description. The objective of the Enzymatic Decontamination Study is to develop and demonstrate a new generation of CB decontaminants based on enzymes and enzyme-compatible materials for use on equipment, vehicles and large areas. Efforts to date have demonstrated highly efficient G-agent enzymes capable of meeting NATO decontamination requirements in two live agent field trials (99.9% destruction of GD in under 15 minutes). Efforts have also shown that the enzymes are capable of functioning in fire fighting foams and solutions, aqueous degreasers and laundry detergents. Emphasis is now being focused on developing enzymatic approaches to VX and HD decontamination. Challenges include increasing the catalytic activity of the V-agent enzymes and developing effective enzyme-based or enzyme compatible systems for blister agents and thickened agents.

7.3.6.3 Functional Areas. The results of the Enzymatic Decontamination Study support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	✓
Large Area Decon	✓

7.3.7 Restoration Operations (RestOps) Advanced Concept Technology Demonstration (ACTD)

7.3.7.1 Sponsor. DoD, DTRA. Point of Contact: Dr. Janet Strong

7.3.7.2 Program Description. The ACTD RestOps is a proposed ACTD with its primary focus involving operational exercises with the users and demonstrations of various technologies designed to facilitate restoration of normal operations at air bases. Discussions are ongoing with PACOM to sponsor the ACTD. At this time the scenario involves an APOD with cargo and personnel contaminated by chemical agent and some biological agents. In addition to providing a technology testbed, this ACTD will also address policy and operational issues such as "How clean is clean?", the level of operational tempo after an attack, and decontamination strategies for a large airbase or facility.

7.3.7.3 Functional Areas. The results of the ACTD RestOps support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	✓

7.3.8 Joint Service Sensitive Equipment Decontamination (JSSED) System

7.3.8.1 Sponsor. DoD.

7.3.8.2 Program Description. The JSSED Program will address the need to be able to decontaminate CB agents from sensitive equipment, aircraft/vehicle interiors and associated cargo. The JSSED system will decontaminate sensitive equipment (avionics, electrical, electronic, and environmental systems equipment), aircraft/vehicle interiors, and associated cargo while in-flight or during ground/shipboard operations. To effectively operate for sustained periods of time, the systems must have the capability to effectively decontaminate sensitive equipment, aircraft/vehicle interiors and cargo to support ground, air, and sea operations. The JSSED Engineering Development effort is scheduled to start in FY01. Engineering Development efforts for vehicle/aircraft interior decontamination is scheduled to transition into the program in FY04. Research studies supporting the JSSED Program are described in the following sections.

7.3.8.3 Functional Areas. The JSSED Program is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	

7.3.9 JSSED: Supercritical Carbon Dioxide Study

7.3.9.1 Sponsor. DoD, U.S. Army. Point of Contact: Mr. Brian MacIver, U.S. Army ECBC, APG-EA MD, (410) 436-5919.

7.3.9.2 Program Description. The $SCCO_2$ study is focused on evaluating the use of $SCCO_2$ technology to determine its viability for use as supercritical fluid extraction system designed for decontaminating sensitive equipment. Study efforts to date include identification of the appropriate industrial base members; the performance of small scale decontamination efficacy testing using HD, GB, and VX; reviewing lessons learned from the terminated NAEDS Program, and the fabrication of a prototype for bench-scale studies. Upcoming efforts will focus on the performance of bench-scale efficacy testing with HD, GB and VX; and studies examining potential effluent treatment approaches, and overall material compatibility. These efforts are scheduled to be completed during FY00 and will support the start of the JSSED Engineering Development efforts in FY01 – FY05.

7.3.9.3 Functional Areas. The results of the $SCCO_2$ study support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	

7.3.10 JSSED: Environmentally Friendly Sensitive Equipment Decontamination System Study

7.3.10.1 Sponsor. DoD, U.S. Army. Point of Contact(s): Dr. John R. Kennedy, U.S. Army ECBC R&T Directorate, APG-EA MD, (410) 436-7696.

7.3.10.2 Program Description. The objective of the Environmentally Friendly Sensitive Equipment Decontamination System Study is to evaluate the effectiveness of advanced vapor degreaser (AVD) solvent systems in removing CB agents from contaminated sensitive equipment. This research effort, initiated in FY98, will study the solubility of simulants for HD, GB, GD, TGD, and VX in candidate environmentally friendly AVS solvent systems. The study will also evaluate the ability of the AVD process to decontaminate biological warfare agents. To date, laboratory scale apparatus has been designed to simulate the AVD process for the performance of the solubility tests. Technical challenges to be studied include making the existing AVD hardware more compact and portable, developing a methodology for destroying the agents removed by the AVD process, and identifying solvents to remove biological warfare agents.

7.3.10.3 Functional Areas. The results of the Environmentally Friendly Sensitive Equipment Decontamination System study support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	

7.3.11 JSSED: Atmospheric Pressure Plasma Jet (APPJ) Study

7.3.11.1 Sponsors. DoE, Los Alamos National Lab and DoD, U.S. Army. Points of Contact: Dr. Hans Hermann, DoE, LANL, and Mr. Joseph W. Hovanec, U.S. Army ECBC R&T Directorate, APG-EA MD, (410) 436-2761.

7.3.11.2 Program Description. The JSSED system APPJ study is focused on evaluating the use of stable, low-temperature plasma containing energetic oxygen species to destroy CB agents. Study efforts performed on the APPJ system developed by Los Alamos National Laboratory have shown the technology to be capable of destroying CW simulants and BW simulants on surfaces. An APPJ system has been installed in a surety laboratory at the U.S. Army ECBC and is currently being tested prior to the start of CB agent studies.

7.3.11.3 Functional Areas. The results of the Environmentally Friendly Sensitive Equipment Decontamination System study support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	

7.3.12 Next Generation Decontamination Kit

7.3.12.1 Sponsor. DoD

7.3.12.2 Program Description. The Next Generation Decontamination Kit Program is intended to replace the current M295 Decontamination Kit. The Next Generation Decontamination Kit will employ the use of new decontaminants (e.g., sorbents) developed over the next several years. The Next Generation Decontamination Kit is proposed to begin Engineering Development in FY04. Completion of the Engineering Development effort is scheduled for FY09 with Production commencing in FY10.

7.3.12.3 Functional Areas. The Next Generation Decontamination Kit Program is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

7.3.13 Next Generation Decontamination Kit: Solid State NMR Approaches in Decontamination Study

7.3.13.1 Sponsor. DoD, U.S. Army. Points of Contact: Mr. Brian MacIver. U.S. Army ECBC R&T Directorate, APG-EA MD, (410) 436-5919 and Dr. George Wagner, U.S. Army ECBC R&T Directorate, APG-EA MD, (410) 436-8468.

7.3.13.2 Program Description. The objective of the Solid State NMR Approaches in Decontamination Study is to investigate the adsorption and reactivity of VX, GD, and HD on inorganic oxides. Efforts conducted include the measurement of the reaction rates of VX, VX simulant, and HD simulant on a variety of zeolites and on nano-sized MgO. A model was also developed to explain the observed reactivity of liquid agent with porous sorbents. Future efforts will focus on continuing the investigation of VX, GD and HD reactivity on other candidate oxides as well as determine the reaction mechanisms and identification of reaction products. This study is being conducted through the leveraging of on-going investigations at the U.S. Army Medical Research Institute for Chemical Defense and the use of nano-size metal oxides as reactive components in protective skin creams.

7.3.13.3 Functional Areas. The results of the Solid State NMR Approaches in Decontamination Study support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

7.4 Proposed/Planned Future U.S. Programs

7.4.1 Joint Service Mini Decontamination System

7.4.1.1 Sponsor. DoD, Joint Service Program

7.4.1.2 Program Description. This is a proposed follow-on program to the Modular Decontamination System. The intent is to develop a lighter, more man-portable decontamination system in lieu of the M17A1 or M21/M22. The goal is to be able to transport this system with 2 soldiers. Supporting Tech Base efforts will be identified and funded in FY02 and then transitioned to Engineering Development in FY04.

7.4.1.3 Functional Areas. The Joint Service Mini Decontamination System is intended for use in the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

7.5 Terminated U.S. Programs

7.5.1 Non-Aqueous Equipment Decontamination System (NAEDS)

7.5.1.1 Sponsor. DoD, U.S. Army ECBC

7.5.1.2 Program Description. In 1983, the U.S. Army ECBC initiated the development of the NAEDS for the CB decontamination of military hardware and electronic equipment. The NAEDS was developed by the Quadrex Corporation as a closed loop system consisting of a pressurized spray of 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113). The NAEDS was configured as a glove box with two pairs of gloves and two hand-held trigger-actuated spray nozzles. Contaminated items were put in the sealed glove box through access doors, sprayed, and removed. The contaminated Freon 113 solvent was collected in an agent neutralizer tank that contained the decontaminate sodium hypochlorite. The Freon was then recycled through a distillation system and stored in a clean tank for reuse.

By the late 1980's the technology utilized by the NAEDS was demonstrated to adequately decontaminate equipment and sensitive equipment. Prototypes of the NAEDS were built and successfully tested. The program was terminated in the early 1990's due to the enactment of environmental legislation prohibiting the use of Freon 113. The Montreal Protocol International Environmental Treaty and the Clean Air Act Amendments of 1990 mandated a production ban on Class 1 ozone depleting CFCs such as Freon 113.

7.5.1.3 Functional Areas. The NAEDS was intended for use in the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	✓
Interior Equipment Decon	
Large Area Decon	

7.5.2 JSSED: Decontamination of Sensitive Surfaces - Ozone Decontamination Study

7.5.2.1 Sponsor. DoD, U.S. Army. Point of Contact: Mr. Joseph W. Hovanec, U.S. Army ECBC R&T Directorate, APG-EA MD, (410) 436-2761.

7.5.2.2 Program Description. The objective of this effort was to determine the effectiveness of the use of ozone to perform interior decontamination efforts. The effort measured the rates of destruction of VX, HD and GD in an 8.5% ozone atmosphere and identified the major reaction products. The study determined that the initial reaction rates of ozone with HD and VX are rapid, however, the reactions do not proceed to completely destroy the agents (97-99%) into non-toxic products. Two thirds of the VX product had the phosphorus-sulfur (P-S) bond intact (such compounds are expected to be highly toxic) while the primary product of the HD ozone reaction was HD-sulfoxide. Based on this failure to convert HD and VX to non-toxic products, this study was terminated.

7.5.2.3 Functional Areas. The results of the Interior Decontamination Using Ozone Study were intended to support development efforts in the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	✓
Large Area Decon	

7.6 International CB Research Decontamination Programs

7.6.1 NATO Project Group 31 – Non-Corrosive, Biotechnology-Based Decontaminants for CB Agents

7.6.1.1 Sponsor. NATO. NATO Members: France, Germany, UK and US. Pending Members: Italy and Turkey. U.S. Point of Contact: Dr. Joseph J. DeFrank (Chairman), U.S. Army ECBC R&T Directorate, APG-EA MD, (410) 436-3749.

7.6.1.2 Program Description. The objective of this Project Group is to coordinate the international research efforts in the development of standardized enzyme-based decontaminants. Through this Project Group facilities are offered to researchers for large-scale, live chemical agent demonstrations of enzyme based systems. Efforts to date include the demonstration of G-agent enzymes capable of meeting NATO decontamination requirements in two live agent field trials (99.9% destruction of GD in under 15 minutes). Study topics supported by the Project Group include the decontamination of chemical agent spills that occur during the Chemical Stockpile Disposal Program (CSDP) enzyme sponges for decontamination of personnel, casualties and sensitive equipment, enhancement of developing sorbent systems, and the replacement of hypochlorite based equipment systems.

7.6.1.3 Functional Areas. The NATO Project Group 31 efforts are intended to support future development efforts in the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	✓
Large Area Decon	

7.7 International Development Programs

7.7.1 Canadian Decontamination Trailer

7.7.1.1 Sponsor. Defence Research Establishment Suffield. Points of Contact: Dr. J.G. Purdon, (403) 544-4106 and Dr. J.M McAndless (403) 544-4635.

7.7.1.2 Program Description. The Canadian Defence Research Establishment Suffield is in the process of developing a decontamination trailer to replace the M12A1 devices previously used by Canadian forces. The trailer will be mobile and self-contained and will find use for Thorough and Small Capacity Thorough Decontamination efforts. A Concept Demonstrator has been designed, fabricated and evaluated in the field. The trailer will have the capability of prewashing contaminated dirty vehicles/equipment, applying liquid decontaminant formulations and/or concentrates, and rinsing off of spent decontaminants at the completion of the operation.

7.7.1.3 Functional Areas. The Canadian Decontamination Trailer Program is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

7.7.2 Canadian Aqueous System for CB Agent Decontamination (CASCAD)

7.7.2.1 Sponsor. Defence Research Establishment Suffield, Point of Contact: Dr. J.G. Purdon, (403) 544-4106.

7.7.2.2 Program Description. The CASCAD is under development for use in the Decontamination Trailer and in 20 L self-contained sprayers to be used for Operational Decontamination of vehicles and equipment. Prototype formulations have been evaluated in a number of field trials as well as been deployed operationally with Canadian Forces in critical peacekeeping areas. The formulation, when applied, coats the target surface with a decontaminating foam that remains in place until rinsed off. It is anticipated that the formulation will be effective against a wide range of CB agents and will be available within the year.

7.7.2.3 Functional Areas. The CASCAD is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

7.8 International Production Programs

7.8.1 Canadian Reactive Skin Decontaminant Lotion (RSDL)

7.8.1.1 Sponsor. Defence Research Establishment Suffield, Point of Contact: Dr. J.G. Purdon, (403) 544-4106.

7.8.1.2 Program Description. The Canadian forces are presently acquiring stocks of the RSDL to be supplied in 500 mL bottles of liquid for use in medical facilities for the decontamination of wounded personnel, instruments, etc., and in personal pouches for personal decontamination of skin, hair and personal equipment. The pouches will contain a sponge-like applicator swatch impregnated with approximately 50 mL of RSDL. The RSDL is a broad-spectrum liquid chemical agent decontaminant that will remove and destroy chemical agents on contact and is safe for use on all intact skin and for limited use in the eyes. RSDL destroys the chemical agents and is safe enough that it need not be removed from the skin or face immediately. An application is being pursued for an Investigational New Drug status and the lotion offers potential as a wound decontaminant.

7.8.1.3 Functional Areas. The RSDL Program is intended to support the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

8.0 "Out-of-the Box" Technology Survey

8.1 Introduction

This section summarizes the results of the study performed by Charles W. Williams, Inc. The effort focused on developing "Out-of-the-Box" ideas for technologically driven crossovers of industrial technologies into military wide area decontamination of CB agents. The study's assumed target is a major logistical support facility operating in a foreign nation.

8.2 Definition of Terms

The following definitions provide general understanding of the differences between ideas and technology applications that reside either "In-the-Box" or "Out-of-the-Box."

8.2.1 "In-the-Box" Ideas.

"In-the-Box" ideas are those that may be categorized as inside the range of conventional boundaries. Therefore, the definition of "In-the-Box" must be linked with the definition of "Out-of-the-Box". Those boundaries are established through concepts that emerge from specialists working within or in direct support of DoD military mission environments and who commit much of their time to decontamination projects related to CB agents delivered directly into military environments as deliberate targets of attack.

8.2.2 "Out-of-the-Box" Ideas.

"Out-of-the-Box" ideas are those that may be categorized as outside the range of conventional boundaries. Therefore, the definition of "Out-of-the-Box" must be linked to a definition of "In-the-Box." Those boundaries may have been established through limitations associated with a technology at a specific point in time or through the technology's application within a specific industry.

8.2.3. Decontamination Target.

Wide area decontamination is a very broad definition. Table 8.1 outlines the operational definition.

TABLE 8.1 DEFINITION OF DECONTAMINATION TARGET	
MISSION	
ENTRY POINT TO RECEIVE MAJOR CARGO OF ALL TYPES REQUIRED TO SUPPORT FIGHTING UNITS ENGAGED IN AREAS REMOTE FROM THIS FACILITY - NO TROOPS	
ACTS AS "DEPOT" AND TRANSFER POINT TO MOVE GOODS TO FORWARD POSITIONS AS RAPIDLY AS NEEDS DICTATE	
RECEIVES BY AIR, SEA OR LAND (VEHICLE/RAIL)	
TRANSFERS OUT BY AIR, SEA OR LAND (VEHICLES/RAIL)	
GEOGRAPHY	
OUTSIDE USA	ACCOMMODATES DEEP WATER OCEAN VESSELS
ABOUT 120 - 200 ACRES WITHIN FACILITY	WITHIN OR NEAR A METRO AREA OF A FOREIGN COUNTRY

TABLE 8.1 DEFINITION OF DECONTAMINATION TARGET			
REQUIRES AGREEMENT OF HOST COUNTRY		SOME INFRASTRUCTURE AND UTILITIES SUPPLIED FROM HOST	
ASSUMPTIONS			
UNDER "RISKS OF CONTAMINATION" LONG TERM - 1 YEAR PLUS		*ENEMY HAS THE CAPABILITY TO DELIVER A VARIETY OF CONTAMINANTS VIA A VARIETY OF MODES*	
DECONTAMINATION OBJECTIVES			
1. MINIMIZE CASUALTIES: DEATH OR FUNCTIONAL IMPAIRMENT OF SITE PERSONNEL		2. NO EXPORT OF CONTAMINATED CARGO OR TRANSPORT EQUIPMENT	
3. RESTORE OPERATIONAL CAPABILITY ASAP		4. REMOVE NEED FOR PROTECTIVE EQUIPMENT ASAP	
5. CONTAIN CONTAMINATION WITHIN THE SITE		6. RESTORE ALL AREAS TO NORMAL ASAP	
SPECIFIC DECONTAMINATION OBJECTS: SKIN AND PERSONAL EQUIPMENT			
OPERATING PERSONNEL		DEPLOYING FORCE PERSONNEL IN TRANSIT	
DRINKING WATER		FOOD & OTHER CONSUMABLES - INCLUDING MEDICINE	
PERSONAL TOOLS & WEAPONS		CLOTHING	
SPECIFIC DECONTAMINATION OBJECTS: EQUIPMENT/ EXTERIOR			
VEHICLES	SHIPS AND MARINE VESSELS	AIRCRAFT	RAILWAY ROLLING STOCK
MATERIAL HANDLING EQUIPMENT & SUPPLIES (MOBILE CARGO)	MATERIAL HANDLING EQUIPMENT (FIXED CARGO)	CARGO	
SPECIFIC DECONTAMINATION OBJECTS: SENSITIVE INTERIOR EQUIPMENT			
INTERNAL ATMOSPHERE	OFFICE EQUIPMENT & SUPPLIES	MEDICAL EQUIPMENT/SUPPLIES	COMPUTERS
WEAPONS CONTROL SYSTEMS	C & C SYSTEMS	COMMUNICATIONS SYSTEMS	
SPECIFIC DECONTAMINATION OBJECTS: LARGE AREAS			
AIRSTRIPS	PORT FACILITIES & DOCKS	RAIL INFRASTRUCTURES	ROAD INFRASTRUCTURES
OPEN STORAGE YARDS	FIXED COMMUNICATION SYSTEMS	PERSONNEL BARRACKS,	RECREATION & MESS FACILITIES
WAREHOUSES	REPAIR FACILITIES	ADMIN. BUILDINGS	FIXED WEAPONS SYSTEMS
UTILITY INFRASTRUCTURES — ON-SITE	UTILITY INFASTRUCTURES BLOCAL	ATMOSPHERE	SOIL & GROUND
GROUND WATER	SURFACE WATER	MARINE ENVIRONMENT	

8.3 Objective

The objective of the "Out-of-the-Box" study was to look at particular technologies and determine if they also can be applied to the decontamination of CB agents. "Out-of-the-Box" ideas are those concepts utilized in all other areas of the economy and/or research communities that maybe feasible for potential crossover into applications related to wide area decontamination of a major logistical support facility. The following sections detail crossover technologies and integrated system concepts to be considered within the military decontamination technical environment.

8.4 Presentation of "Out-of-the Box" Ideas

The "Out-of-the-Box" ideas are presented in four different sets drawn from different perspectives.

8.4.1 Crossover Potentials.

Crossover potentials are technologies or technology capabilities that have the potential to be adapted for use in the host environment. This process is related to the traditional notion of technology transfer. Crossover potentials, however, are directly related to the specific customized codes and integrated database developed for this study.

8.4.2 Decontamination Technologies Toolkit.

The Decontamination Technologies Toolkit is a complete set of "Out-of-the-Box" ideas. The toolkit builds upon the technology's crossover potential, relating strategies specific to wide area decontamination and application areas.

8.4.3 Integrated Systems Concepts.

Integrated systems concepts are those concepts that organize information into higher level integrated ideas. They combine crossover potentials and toolkit components into systems, which can be employed for wide area decontamination. In this step, additional insights are added based upon analogies. For example, the use of commercial systems for on-site portable storage of liquefied customized gas mixes that can be vaporized under pressure at the proper moment. Another such analogy is the concept of refrigeration systems in transport vehicles which serves as an example of over pressurizing an internal space "on demand" or on a remote, individual container or vehicle.

8.4.4 Scenarios.

Scenarios portray how "Out-of-the-Box" ideas relate to decontamination requirements associated with specific CB agent threats. The scenario is the highest level of synthesis. It provides the most direct connection between "Out-of-the-Box" concepts and explicit military application of the ideas.

8.5 Criteria for Relevance

In addition to being "Out-of-the Box" and target specific, the study focused on identifying ideas that are relatively advanced toward application for near-term military payoff. Therefore, the following criteria were applied for technical relevance during the literature review:

- Judgmental ideas based upon applications in the commercial and industrial economic sectors that are not directly related to military operations.

- Each idea must encompass concepts that are already commercialized or in development, although experimental research demonstrating very high decontamination potential could be conceptually employed.

- Each idea must directly relate to a specific functional area.

- The ideas should be derived from a comprehensive search of commercial electronic databases and the analytical experience of the study team.

- The definitive technical feasibility of an idea would not be assessed; instead, the ideas would be identified and then left for assessment specialists within the DoD decontamination community.

- The study team would not determine whether the military decontamination community had already studied an idea.

8.6 Technical Approach

8.6.1 <u>Methodology.</u>

To initiate the effort, it was assumed that the best stimulus for the "Out-of-the-Box" analysis would be to develop an illustrative profile of the type of industrial situations in which decontamination efforts may need to be accomplished. Figure 8.6.1 illustrates the project's logic flow.

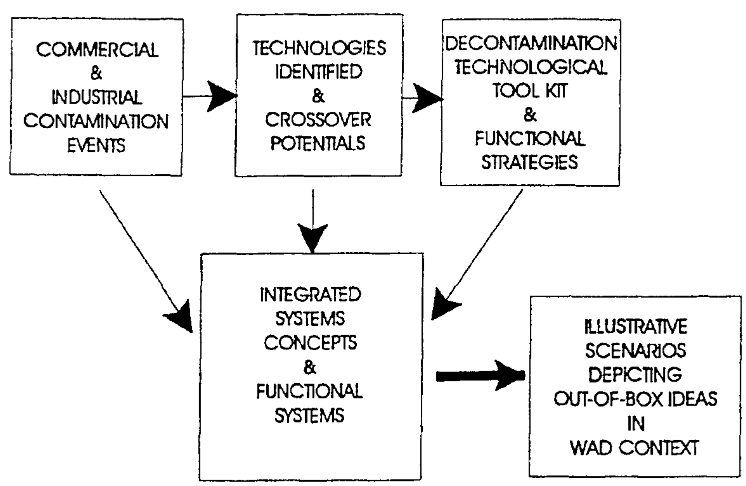


Figure 8.6.1 "Out-of-the-Box" Logic Flow

Experience has shown that "Out-of-the-Box" thinking generally comes from relatively unconstrained analysis of comprehensive data inputs that are developed from a paradigm both independent of and external to the activities and technical disciplines for which the crossovers are intended. In this sense, the results are a blend of an art form, judgment honed by non-specialized experiences across a wide range of subjects, and analytical techniques designed to support this type of assessment.

Beginning with the illustrative profile of the types of industrial situations in which decontamination efforts may need to be accomplished, the research team derived information from commercially available electronic databases. The project team imposed no limits, but characterized decontamination as whatever the literature said that it was. Before initiating data acquisition, the team developed an operational definition outlining the features of the military targets to which the analysis was directed. This was followed with the development of a set of criteria to evaluate potential ideas.

From this starting point, an initial sample of documents was drawn using the terms "decontaminate or contaminate". The assumption was that authors and editors of the documents would define what industries considered to be conditions of contamination and/or decontamination. It was determined that commercial industry does not consider decontamination to be a technology. The term is highly skewed to define techniques related to nuclear clean up, waste management and blood quality. A variety of search strategies were then tested to provide a more comprehensive and representative baseline of data for purposes of analysis.

After the initial analysis, team members developed customized codes to classify the information and develop the conceptual framework. This coding approach is used for purposes of comprehensive analysis and assessment. Time and resource constraints limited the amount of data gathered and analyzed. Therefore, only documents from the last 2 years, 1997 and 1998, could be reviewed. Additionally, the project team exploited very selective high pay-off database sources. Researchers used sampling techniques that provided coverage in a variety of industries. This approach, while comprehensive within its time boundaries, provides a picture that is somewhat qualified as it relates to decontamination. Additional analysis performed within a larger time span would help to clarify long range decontamination trends.

All data inputs were converted to a common database format to facilitate integrative analysis. The inputs were then coded with the customized structure designed for this project. All documents within a common code were then assembled into sets and synthesized as a series of discreet (and at this point independent) cells of information. During execution of this process the study team generated potential crossovers as the insights occurred. The integrated summaries across codes were analyzed and the team developed a table of potential crossover ideas. Analysts expanded these ideas into a set of crossover technical concepts.

The final step was to synthesize crossover technology at a higher level by formulating integrated system concepts. Team members moved from collection of information about technology to the generation of intelligence and the synthesis of technical information. Rather than a one to one correlation to the decontamination tools, the integrated system concepts categorizes sets of information into separate but integrated systems. The foundation of this step is the decontamination toolkit. For this level, the component technologies were structured against decontamination technical employment and possible decontamination events to construct "Out-of-the-Box" concepts which could be available to emergency response teams and environmental managers for both wide area decontamination and full long term site remediation.

8.6.2 The Coding Structure

A summary of the structure used to summarize the data is provided below. A detailed description of how this structure was used to synthesize the data collection can be found in Appendix E.

- Level 1: Defines the general category by which this project can be separated from others; i.e. ZZDECON:
- Level 2: Defines the substrate upon which decontamination techniques are employed; i.e. SUB: BUILDING-INTERNAL
- Level 3: Defines the type of event which is involved; i.e. EVE: TREATMENT-PROCESSING
- Level 4: Defines the type of contaminate to be neutralized; i.e. CHE: PESTICIDE or CHE:TOXINS

8.6.3 The Synthesis Structure

Finally, the information collected was put into the following format that is specific to the database structure.

ZZTECDECON: SUB: AIR-ATMOSPHERE; EVE: ACCIDENT-EMISSIONS/CHE:MULTI
##Update: 9802
##Notes:
##Overview:
##Impact:
##Industry:
##Owners:
##Remediators:
##Technique proactive
##Technique remedial:

TABLE 8-2 OVERVIEW CONCEPTUAL FRAMEWORK
(ROWS DO NOT CORRELATE ACROSS THE COLUMNS)

COMMERCIAL/INDUSTRIAL EVENTS					
[illegible] CONTEXT	INDUSTRIES INVOLVED	DECONTAMINATION TECHNOLOGIES	DECONTAMINATION TECH TOOL KIT	INTEGRATED SYSTEMS CONCEPTS	ILLUSTRATIVE SCENARIOS
a. Agricultural Crops	Automobile	Bioremediation	Barriers		Atmospheric release
b. Air & Atmospheres	Chemical				of chemical agents
c. Asphalt	Cosmetics	Freeze dried enzymes	Prevention		
d. Buildings	Electronics		Coatings		Release of biological
e. Cloth clothing	Equipment	Biocatalytic hydrolase			agents into an
f. Concrete	Environmental	degradation	Immediate remedial in		administrative
g. Equipment	Extraction facility		place		facility
h. Fluids	Food fuel gases	Filtration	a. no residue		
i. Glass	Metals paint		b. residue		Personnel exposure
j. Masonry	Petrochemical	Water dispersible			to biological agents
k. External	Petroleum	double packaging	Deferred on-site		in showers
l. Medical	Filtration		residual treatment		

TABLE 8.2: OVERVIEW CONCEPTUAL FRAMEWORK (ROWS DO NOT CORRELATE ACROSS THE COLUMNS)					
COMMERCIAL / INDUSTRIAL EVENTS					
CONTEXT	INDUSTRIES INVOLVED	DECONTAMINATION TECHNOLOGIES	DECONTAMINATION TECH. TOOL KIT	INTEGRATED SYSTEMS CONCEPTS	ILLUSTRATIVE SCENARIOS
m. Research n. Metals o. Manufacturing p. Packaging q. Personnel r. Pipes & Tubes s. Plastic t. Materials u. Sites v. Soil w. Surfaces x. Vehicles y. Water z. WEAPONS	Industrial Cleaning Industrial gases Mining Nuclear Paints & coatings Petroleum Pharmaceutical Pharmaceutical Plastics Pipelines Plating powder Public safety Public health Pulp paper Sensor Steel Textiles & clothing Waste treatment Water purification Weapons	Permeable reaction walls Surfaces decontamination Silicon elastomers Electron beam neutralization Solvate electrons Protective clothing Electro spinning Skin treatments Medical techniques Controlled atmospheres Over pressure Vapor clouds			Infusion of biological agents into storage facility

8.7 Key Conclusions

The concept of exploring commercial decontamination practices, systems and concepts is valid and can have significant benefit to military environments. An ongoing commercial decontamination technology monitoring process is more than justified and should be a consideration when defining future decontamination research and development strategies. Trends in decontamination technology are shifting from concepts of contaminate specific decontamination tools to a multipurpose tool(s) for treating many different contaminates concurrently. Industrial decontamination technologies may be categorized into the following concepts:

- Prevention of contamination
- Minimization of contamination
- Decontamination without residue
- Short term or long term decontamination with residue and requiring remediation

There appears to be a major conceptual difference between industrial and military application of decontamination technology. The commercial sectors involved in decontamination apply or investigate applications that avoid site contamination through proactive measures and therefore minimize clean up after a contaminating event. In contrast, military efforts appear to emphasize technologies that decontaminate in reaction to an event.

Several industries employ technologies that have applicability to military wide area decontamination. Some of these technologies are currently in commercial application and appear to be transferable to a military context. Emerging technologies demonstrate great promise, particularly those providing proactive protection to personnel and operations, but need further development to be readily available and appropriate for tactical use. Appendix F contains a listing of the different companies/ organizations that users identified as suppliers of processes, services, products or equipment for remediation of biological or chemical contamination. This appendix also contains a listing of the different industries in which decontamination activities either took place or in which suppliers of remediation are based.

The ability to significantly reduce contamination and to decontaminate large areas is possible within both the current and mid-term potential of existing technology. Emerging technology provides an opportunity to take proactive measures to minimize actual contamination and begin mitigation while reducing extensive site remediation. Use of advanced proactive technology will markedly diminish the requirement to mitigate or decontaminate the run-off or waste generated by many reactive techniques and technologies. The technology is available to monitor contaminated assets before and during decontamination operations to ensure that CB agents are not transported off site to clean areas.

8.8 Technologies Identified

8.8.1 Bioremediation

Bioremediation, or the biological treatment of wastes, usually is associated with the remediation of organic contaminants. Similarly, there is an increasing body of literature and expertise in applying biological systems to assist in the bioremediation of soils, sediments, and water contaminated with inorganic compounds including metals, radionuclides, nitrates, and cyanides.

Bioremediation may be the foundation of a total systems approach to site decontamination and on-site remediation. In this approach, a facility-designed process composed of many different technologies is organized into systems. These systems execute concurrently to decontaminate large areas (to include all materials in the area) and restore the environment. The goal is to allow the site and its buildings to be returned to a condition of unrestricted use.

Commercial technologies include:

8.8.1.1 Microbiological Approach. This technology involves augmentation of the contaminated site with one or more species of contaminant-specific degrading organisms. The microorganisms come into contact with the contaminant and metabolize it, usually as a source of food and energy. The digestion process leaves less toxic and more stable chemical forms of the contaminant, along with other inert byproducts such as water, carbon dioxide, methane and hydrogen. This process, if successful, remediates contaminants to below levels of regulatory concern. Additionally, while chemicals such as polychlorinated biphenyl and trichloroethylene found in groundwater resist the chemical degradation processes, the bacteria involved in bioremediation can successfully metabolize these complex chemicals.

8.8.1.2 Microbial Approach. This technique involves adjusting certain physical and chemical factors at a site to enhance degradation. The microbial approach can be used at most sites. Contaminated soils may be bioremediated by in-situ techniques, land farming, or composting. Toxic organic waste biodegradation incorporates identification of microbes, determination of the optimal conditions for degradation, establishment of the metabolic pathways involved in degradation, identification and localization of the genes involved, identification of suitable microbial strains for practical application and development of practical engineering processes. This includes adjusting the site's physical or chemical factors through techniques such as land shaping, applied electric fields to contaminated soil, and enhanced delivery of nutrients injected into the soil to help natural biological organisms to degrade the target agent.

8.8.1.3 Aerobic Biodegradation. Aerobic biodegradation, or the use of oxygen as the decontamination tool, occurs naturally if sufficient oxygen and nutrients are present in the soil or groundwater. Soil venting or vapor extraction will remove hydrocarbons from unsaturated soil and reduce leaching to groundwater. Groundwater cleanup can occur in an underground aquifer.

8.8.1.4 Biofilters/Slurry Bioreactors. Bioslurry treatment is designed to destroy hazardous organic constituents and to convert them to carbon dioxide and water. A raw waste stream is preheated and chemically treated before being fed to the centrifuge. The centrifuged waste is biologically processed using the tank-based bioslurry reactors. From the centrifuge, the residual solids are fed through bioslurry reactors in series, are air/oxygen sparged and mechanically agitated. Ammonia and phosphoric acid are continuously fed as nutrients. This environment fosters aerobic microbial degradation, and consequently the organic components of the waste are converted to carbon dioxide and water.

8.8.1.5 Phytoextraction. This refers to the use of metal-accumulating plants that extract metals from the soil and concentrate them in the roots and shoots. The stem and leaf systems can be harvested for metals recovery or disposal. Disposal volumes should be significantly lower than potential excavated soil volume. Plants that are promising for phytoextraction include sunflowers, the mustard plant, and some varieties of broccoli and cabbage that have the required tissue mass to absorb large quantities of metal. These plants tend to pull the metal up into their shoots, and grow relatively quickly.

8.8.1.6 Rhizofiltration. This technique is the use of plants to absorb, concentrate and remove toxic metals from polluted streams. Sunflowers are particularly adept for rhizofiltration. Also, flow-through rhizofiltration systems can be designed for removing contaminants from water by pumping the waste through a trough planted with accumulator plants. The water moves through the cycle until it is clean enough to be discharged.

8.8.1.7 Phytostabilization. This is the most experimental form of phytoremediation. It is based upon the use of plants to eliminate or reduce the availability of toxic metal in soils. The process serves to collect contaminants in root systems so that they are not subject to leaching, migration, ingestion or other paths of exposure. Phytostabilization also provides vegetative cover for contaminated soils, making them less likely to erode or leach.

8.8.1.8 Thermal Desorption. Although not technically a bioremediation technique, thermal desorption is often used in landfill and Brownfield systems for treating contaminated water and organic solids. Waste materials are heated to at least 320 degrees Celsius to volatize water and the organic contaminants. A carrier gas or vacuum system transports the heated material to a gas treatment system. Off gases usually are routed to an afterburner where they are destroyed. This technique is usually used off site when a large amount of soil and or water permeated with semi-volatile organic compounds must be treated. It is commonly used to treat soil contaminated with polynuclear aromatic hydrocarbons.

8.8.1.9 Application Areas. Bioremediation may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	✓

8.8.1.10 Commercial Applications.

- Emergency response to an accident
- Long-term site decontamination
- Long term site/facility decontamination-return to safe use
- Waste treatment
- Environmental management

8.8.1.11 Potential Crossover Adaptations.

- Proactive design of a site with bioremediation technologies already in place.
- Mitigation of attack begins immediately.
- Long-term environmental reuse possible

8.8.2 <u>Freeze Dried Enzymes</u>

A mixture of enzymes can be freeze-dried into a powder for easy storage and transport. The mixture would be added to any available onsite water and sprayed onto contaminated equipment or areas with conventional decontamination or fire fighting equipment. Several enzymes have been freeze-dried successfully, permitting their storage at room temperature for nearly a year with virtually no loss in activity.

8.8.2.1 Application Areas. Freeze-dried enzymes may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	✓

8.8.2.2 Commercial Applications

- Decontamination
- Large area remediation

8.8.2.3 Potential Crossover Adaptations

- Permits on-site storage of many decontamination agents for a longer period of time.

8.8.3 Biocatalytic Degradation

Organophosphorous acid anhydrolase enzymes are effective decontaminants of toxic chemicals and for deactivating chemical nerve agents. The technology is used extensively to chemically convert environmental pollutants and pesticides, decontaminate liquid or gaseous phase toxic chemicals at commercial waste sites and to dispose of chemical weapons stockpiles. A spin off sub-technology utilizes cross-linked enzyme crystals, which seem to be less soluble, react well in various solvents and are stable and therefore reusable. The enzyme can be cloned, stored dry and reconstituted in a buffered solution for use to decontaminate water (drinking, waste, ocean) or as a foam to contain blasts or decontaminate water and other liquids. The foam-based option can be used for on site decontamination of chemical nerve agents.

8.8.3.1 Application Areas. Biocatalytic degradation may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	✓

8.8.3.2 Commercial Applications

- Waste Treatment
- Neutralizing Toxic Chemicals
- Neutralizing Explosives and Chemical Nerve Agents

8.8.3.3 Potential Crossover Adaptations

- Decontaminating nerve agents
- Waste treatment on site
- Purifying water and liquids

8.8.4 Filters

Membrane filters take many forms: fiber, metallic, polymeric, glass, thin film, and granular. In addition to the standard filtration systems such as fiber and granular bed, many forms of high efficiency particulate filtration, such as microfiltration and nanofiltration are now used to separate, exclude or trap particulates, microbes, viruses and other chemical or biological entities, either for removal, study or processing.

8.8.4.1 Application Areas. Filters degradation may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	✓

8.8.4.2 Commercial Applications

- Air filters for work areas in industry, business or homes.
- Cleaning and washing filters for textiles, laundry, and other fabrics.
- Carbon and carbon composite filters used in a variety of settings including water purification and waste treatment.
- Hospital filters for rooms, intensive care units (ICU), operating rooms (OR), controlled atmosphere systems, masks, chemical analysis, medical equipment cleaning
- Micro- and nanofilters for medical research, biochemistry and electronics (semiconductor manufacturing).
- Nanofiltration in the beverage industry to separate contaminants from liquids: alkalines, chloride, sulphates and organics containing microbes.

8.8.4.3 Potential Crossover Adaptations

- Improved filtration for command center, sensitive rooms & equipment, vehicles, masks for personnel.
- Develop a decontamination filtration system combining ultrafiltration with CB neutralizers, trapping and neutralizing CB agents as they reach the exterior of an enclosed space.

8.8.5 Water Dispersible Double Packaging

Water dispersible double packaging is for packaging aqueous products without the film disintegrating from the inside. It dissolves in the same way as traditional water-soluble film when plunged into water. The film, only a few microns thick, is coated with a special non-water-soluble coating on its interior face. When immersed in water the coating is dispersed into tiny particles that have no effect on the chemical reactions. The PVA film is fully biodegradable. The material enables paired bags containing incompatible products, to be stored in the same packaging without cross contamination.

8.8.5.1 Application Areas. Water dispersible double packaging may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	✓

8.8.5.2 Commercial Applications

- Packaging in the food and pharmaceutical industries

8.8.5.3 Potential Crossover Adaptations

- Could be used to store decontaminate agents in liquid form that could be activated at the proper time for decontamination activities on liquids, containers and other sensitive articles for which immersion is acceptable.
- Explore the use of this concept on a larger scale for decontamination of larger equipment or cargoes that can be covered by a liquid.

8.8.6 Permeable Reaction Wall

A permeable reaction wall is installed across the flow path of a contaminant plume, allowing the water portion of the plume to passively move through the wall. These barriers allow the passage of water while prohibiting the movement of contaminants by employing such agents as chelators (ligands selected for their specificity for a given metal), sorbents, microbes and others. The contaminants either will be degraded or retained in a concentrated form by the barrier material. The wall could provide permanent containment for relatively benign residues or provide a decreased volume of the more toxic contaminants for subsequent treatment.

8.8.6.1 Application Areas. The permeable reaction wall may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

8.8.6.2 Commercial Applications

- Emergency response cleanup

8.8.6.3 Potential Crossover Adaptations

- Design-in large areas as a proactive measure in establishing a total decontamination system

8.8.7 Surface Decontamination

Several technologies exist, including biocidal liquids, sterilizing inert gas lamps, and chemical solutions and sprays that neutralize toxic chemicals. Inert gas lamps clean surfaces by utilizing UV light and other high frequency non-heating irradiation in order to eliminate pathogens without heating or use of chemicals. The nuclear waste industry has developed several technologies that remove the radioactive surface contaminant on concrete. One method, electro-hydraulic scabbling, produced powerful shock waves and intense cavitation by a strong pulsed electric discharge in a water layer at the concrete surface; high impulse pressure results in stresses which crack and peel off a concrete layer of controllable thickness. Scabbling produces contaminated debris of relatively small volume that can be easily removed, leaving clean bulk concrete. Another concrete decontamination approach applies ionizing radiation to the concrete surface to decontaminate it.

8.8.7.1 Biocidal Paint/Coatings. These are biocidal and chemically decontaminating coatings for surfaces of solid objects and structures.

8.8.7.2 Surface Sterilization. This is a process where UV, ionizing radiation or other non-chemical activity sterilizes a surface, including crevices and cracks.

8.8.7.3 Surfactant Solutions. This is a chemical that interacts with the surface of another chemical, enabling the joining of molecule at the surface to clean dirt.

8.8.7.4 Dry Ice Pellet/Water Ice Crystal Surface Cleaning. This process uses carbon dioxide pellets that are non-toxic and less abrasive. The pellets are injected into a line that is pressurized and feeds a blast nozzle. A jet of high-velocity air and pellets are then sprayed onto the surface being cleaned. Pellet size, hardness, and velocity can be altered for a range of cleaning needs.

8.8.7.5 Application Areas. Surface decontamination may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	✓

8.8.7.6 Commercial Applications

8.8.7.6.1 Biocidal, Surface Sterilization, Surfactant Solutions

- Decontamination of surfaces involving chemical, nuclear or biological toxins or pathogens.
- Waste treatment applications.
- Environmental control of facility work areas and surrounding site.
- Other contamination from chemical, petroleum and agriculture manufacturing

8.8.7.6.2 Dry Ice Pellet/Water Ice Crystal Surface Cleaning

- Cleaning precise equipment: electronics, equipment manufacturing
- Cleaning nuclear waste sites
- Cleaning chemical or petroleum spills
- Cleaning concrete or solid surfaces: buildings, structures, roadways, flat surfaces

8.8.7.7 Potential Crossover Adaptations

8.8.7.7.1 Biocidal, Surface Sterilization, Surfactant Solutions

- Decontamination of concrete or asphalt work areas, runways, etc.
- Use of technologies limiting "runoff" and site restoration problems.
- Portable structures for controlled atmosphere decontamination of equipment and vehicles.

8.8.7.7.2 Dry Ice Pellet/Water Ice Crystal Surface Cleaning

- Decontamination of roadways, loading area and runway surfaces.
- Decontamination of sensitive solid equipment, interiors, probably using smaller decontamination equipment with settings that are different from large-scale application.
- Decontamination surfaces of buildings and structures, large throughput containers.

8.8.8 Remote Decontamination - Robotics

A robotic arm with several joints is mounted on a telescoping mast, which lowers the arm into a tank (or other contaminated area). When it is retracted, it passes through a high-pressure water spray decontamination system into a box. Such a unit can be mounted on a truck so it can be moved to different locations. Complementary equipment includes a trailer to allow workers to remotely control the robots with a fiber optic link from more than 900 feet away. A video system is used to observe the robotic arm in the enclosed area.

8.8.8.1 Application Areas. Remote Decontamination - Robotics may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

8.8.8.2 Commercial Applications

- Used in radioactive environments in nuclear storage tanks.
- Used in the chemical industry in tanks containing toxic chemicals.

8.8.8.3 Potential Crossover Adaptations

- A gaseous or liquid decontaminant can be attached to the tubing that is connected to the robotic arm. Decontamination in an enclosed space can be achieved without personnel being in the contaminated area

- Decontamination of highly toxic spaces within a large area (accessible and enclosed spaces). This includes vehicles or rooms that need to be decontaminated in order to protect personnel involved in decontamination activities.

8.8.9 Ozone Treatment and Washing

Ozone, a form of oxygen, has three atoms per molecule as opposed to two. Its life span is approximately 20 minutes, at which time it degrades to oxygen, therefore leaving no chemical residue. Ozone is 3000 times more effective than chlorine in disinfecting from biological agents. Ozone is produced artificially using oxygen and electricity, thereby eliminating the need for transportation and storage to specific sites where biological decontamination is needed. Injected into water with contaminants, it works best at ambient to cold temperatures, making it practical to use. Portable ozone washers from small, through moderate and large size are commercially available

8.8.9.1 Application Areas. Ozone treatment and washing may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	

8.8.9.2 Commercial Applications

- Industrial Cleaning
- Hospital and Medical disinfecting
- Water and air treatment systems
- Textiles and Clothing
- Food processing
- Medical & Pharmaceutical Research

8.8.9.3 Potential Crossover Adaptations

- Use for purifying drinking water and other water supplies
- Use for washing contaminated cloth and clothing
- Use to purify food and other consumables
- Use in a recirculating water system, avoiding need for outside water supply if site is not close to a safe water supply
- Use for cleaning equipment, vehicles and surfaces where cleaning time is under 20 minutes and multiple surfaces can be treated with an ozone-treated washing solution

8.8.10 Ultrasonic Cleaning

A cleaning process using pure carbon dioxide added to a product during rinsing, drying and ultrasonic cleaning. Deionized water acts as a solvent, creating static charges of thousands of volts, attracting contaminants and pitting surfaces. Carbon dioxide reionizes water, restoring its electrical conductivity without reintroducing impurities eliminated by deionization. This is also beneficial for solvents used in ultrasonic cleaning. In this process there is less of an environmental hazard and less damage to surfaces on the product.

8.8.10.1 Application Areas. Ultrasonic cleaning may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	

8.8.10.2 Commercial Applications

- Electronics Industry for microchip wafer manufacturing

8.8.10.3 Potential Crossover Adaptations

- Although serving a different purpose, the ultrasonic cleaning itself and the technique for lessening hazardous runoff may have crossover potential for cleaning sensitive equipment and solid surfaces after an immediate crisis is over.

8.8.11 Ultraviolet Purification

Some solar decontamination processes for water were developed using TiO_2 photocatalysts supported on silica-based material. The supported catalysts were systematically optimized with respect to catalyst type, catalyst dosage, silica-based support material, particle size, catalyst/support bonding, and calcination temperature. The optimized supported catalysts outperformed an optimized slurry catalyst under identical operational conditions and had a reaction rate four times that of the slurry catalyst. Trichloroethylene (TCE) as a model compound was also used to investigate the impact of solar irradiance, influent concentration, pH value, and hydraulic loading. Supported photocatalysts displayed high light efficiencies over a wide range of weather conditions. An apparent quantum yield of 40 was obtained in a rainy late-afternoon experiment. The complete mineralization of TCE was achieved, and in addition, background natural organic matter (BNOM) in local surface water did not interfere with the degradation significantly.

8.8.11.1 Application Areas. Ultrasonic purification may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

8.8.11.2 Commercial Applications

- Decontaminating Packaging Board of Different Surface Compositions.
- Volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC) Destruction Process
- Municipal Wastewater Disinfecting Systems

8.8.11.3 Potential Crossover Adaptations

- Surface decontamination of equipment and buildings
- Proactive water protection
- Drinking water decon

8.8.12 Silicon Elastomers - Under Water Cleaning

A silicon elastomer is a type of coating for surfaces employing complex organic compounds found effective as biocides. They possess leaching capabilities that protect ships against biological growth on ship hulls.

8.8.12.1 Application Areas. Silicon elastomers - under water cleaning may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

8.8.12.2 Commercial Applications

- Shipping Industry
- Cleaning

8.8.12.3 Potential Crossover Adaptations

- Cleaning or proactive protection of underwater surfaces in ports. May have applicability for decontamination against biological agents.

8.8.13 Electron Beam Accelerators

The accelerators destroy more than 99 percent of many hazardous chemicals. Chemicals that are highly resistant to waste treatment, such as phenols, can be reduced by 80-85 percent by accelerators. Beams have 1.5 million volts of energy and each pulse lasts about 100 nanoseconds (one nanosecond is one billionth of a second). The pulsed beam allows separation of the treatment process into two phases, In the first phase, electrons react with water molecules, making chemical entities known as free radicals, which are highly reactive. In the second phase, the free radicals react with organic contaminants to produce such non-hazardous substances as carbon dioxide, water and salt. At present, researchers believe it may be possible to use electron-beam technology in conjunction with nuclear waste treatments to dispose of mixed waste (typically composed of radioactive material, hazardous chemicals, and water).

8.8.13.1 Application Areas. Electron beam acceleration may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

8.8.13.2 Commercial Applications

- Mixed Wastes Treatment
- Nuclear Waste Treatment
- Medical Waste Treatment
- Site Remediation

8.8.13.3 Potential Crossover Adaptations

- Design-in large areas for quick response decontamination and remediation

8.8.14 Chemical Neutralizing

Chemical neutralization is a rapid and chemically precise recovery or recapture of toxic chemicals through a chemical process. Used to destroy toxic chemicals for protection of personnel or to recover valuable components of a solution. The neutralizing solution can be sprayed as a gas, foam or liquid, embedded on a surface or applied or encapsulated to be activated chemically, electrically, or by a device.

8.8.14.1 Application Areas. Chemical neutralization may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	✓

8.8.14.2 Commercial Applications

- Chemical Industry cleanup
- Waste treatment
- Metals and plating industries
- Civil Defense

8.8.14.3 Potential Crossover Adaptations

- Protection of personnel, food and consumables.
- Protection or decontamination of equipment, vehicles or covered cargo.
- Decontamination of surfaces of large areas, including buildings, runways, and loading areas
- Long term remediation of ground or water, both on or off site.

8.8.15 Solvate Electron Technology

Solvate electron technology (SET) is a non-thermal, low-pressure process for destruction of chemical agents in soil and on surfaces. It emits no off-gases and destroys contaminants, leaving the matrix undisturbed. The process works by placing the toxic substance to be destroyed in a tank with anhydrous, or water-free, ammonia. Metallic sodium is then added to the mix and dissolved in the ammonia. When the resulting solution turns a vivid blue, it indicates the toxic substance is being neutralized. The resulting mix -- now non-toxic -- is removed and any by-products needing further processing can receive further treatment. The ammonia solution used in the process can be recycled and reused.

8.8.15.1 Application Areas. Solvate electron technology may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	
Exterior Equipment Decon	✓
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	✓

8.8.15.2 Commercial Applications

- Used to destroy PCBs, dioxins and pesticides.

8.8.15.3 Potential Crossover Adaptations

- Destroy chemical nerve agents and decontaminate surfaces contaminated by chemical agents.

8.8.16 Protective Clothing

A new CB suit increases comfort and permits the maximum use of fine motor skills. Researchers found that the CB Combat Suit (CBCS) offered significantly better wearer performance under all such conditions than the existing suit. Surprisingly, the performance matched that of subjects wearing the Australian Defence Forces (ADF's) standard-issue cotton-blend combat uniform. The fabric's outer and inner layers of cotton enclose a middle layer of small carbon spheres that absorb vapor and particles, providing protection for up to 24 hours. According to the Australian Defence Science and Technology Organisation (DSTO), the spheres retain their properties when wet with perspiration and can be decontaminated up to 10 times before a reduction in protection is likely. Whereas the MkE4 suit is an over garment worn on top of the combat uniform, the CBCS can be worn directly on top of underwear. This increases comfort and permits the maximum use of fine motor skills.

8.8.16.1 Application Areas. Protective clothing may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

8.8.16.2 Commercial Applications

- Australian Military CB Combat Suits

8.8.16.3 Potential Crossover Adaptations

- Increased productivity and protection of decontamination teams.
- Increased productivity and protection of troops during attack

8.8.17 Electrospinning Polymer Fibers Protective Clothing

Electrospinning involves the suspension of a droplet of polymer solution charged to a high voltage. The solution is then projected towards the intended target, forming a continuous multi-filament fiber of polymer. The multi-filament dries and becomes an interconnected web of small fibers.

8.8.17.1 Application Areas. Electrospinning polymer fibers protective clothing may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

8.8.17.2 Commercial Applications

- Clothing
- Equipment
- Household appliances and containers
- Synthetic rubber
- Semiconductor chip manufacturing

8.8.17.3 Potential Crossover Adaptations

- Electrospinning of polymer fibers creates ultra-thin layers of protective clothing that protects against CB agents.
- Decontaminates the CB agents while the clothing is being worn.
- Allows greater mobility while being worn, reducing lost time during modified operating procedures
- Allows personnel to continue operational behavior longer, rather than moving from operations to specified decontamination area.

8.8.18 Protective Skin Treatment

Gloves in A Bottle is a commercial product that provides skin protection against most chemicals including common household and workplace detergents, solvents, paint thinners, pesticides and other skin irritants. The unique nature of Gloves in A Bottle is that, although it is formulated to naturally soften hands like the best skin lotions, it was originally developed to create a protective shield or barrier for the skin. Assimilated into the outer layer of the skin, the product forms a web between the dead skin cells, resulting in a one way barrier which helps prevent most irritants and toxins from penetrating the skin.

8.8.18.1 Application Areas. Protective skin treatment may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

8.8.18.2 Commercial Applications

- Protection & treatment of skin during manufacturing or decontamination.
- Cosmetics
- Sunscreen
- Protection from allergens

8.8.18.2 Potential Crossover Adaptations

- Protection of a decontamination team without gloves provides better manual dexterity
- Protection for exposed areas of the body prior to attack
- Temporary protection of personnel until proceeding to a decontamination or safe area

8.8.19 Medical

8.8.19.1 Vaccines. A new type of oral vaccine may eventually lead to protection against a range of diseases, and result in a vaccine that may be eaten with food. For example, the virus causing cholera, when administered orally in food was found to give immunity against the pathogenic strain of the virus. Tests at the Fedric Institute of Plant Protection and Toxicity, showed the vaccine has high efficacy and low toxicity levels. To achieve the end result, the scientists cloned a cholera toxin gene in plasmid and engineered it in such a way that it's immunogenic, nontoxic part was retained and toxic part deleted. This gene was then introduced into non-toxinogenic clinical isolate. Molecular biologists at Thomas Jefferson University, Philadelphia, have created an oral vaccine against botulism. The researchers will use it as a prototype in developing future vaccines for other diseases, such as anthrax, diphtheria, whooping cough, and tetanus. Eventually the research will lead to a range of oral vaccines that will be inserted into common foods.

8.8.19.2 Antidotes. A new principal for delivery of protection against chemical agents is being researched. Since many intravenous antidotes will not remain stable for any length of time in liquid form, genetically engineered forms will be developed that can be inserted into common foods.

8.8.19.3 Gene Therapy Research. It is predicted that the human genome will be sequenced by the year 2005. The information is expected to lead to radical new treatments for a broad range of human disease, including CB agents. It may also provide information about biochemical pathways that are susceptible to peptides and other compounds, which could thus be exploited as a hostile act to damage human health.

8.8.19.4 Application Areas. Vaccines, antidotes, and gene therapy research may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	
Interior Equipment Decon	
Large Area Decon	

8.8.19.5 Commercial Applications

- Disease Treatment
- Emergency Medicine
- Immunology
- Public Health

8.8.19.6 Potential Crossover Adaptations

- Easier delivery of vaccines against new forms of biological agents to troops in the field
- Long shelf-life field packs of orally administered antidotes in food bars
- Continually evolving treatments for exposure to contaminates

8.8.20 Internal Controlled Atmospheres - Special Gas Atmospheres

Several industries use controlled atmospheres as basic systems essential to their work. Special medical gas systems in hospitals provide patients with essential atmospheres for comfort or survival. Hospital operating rooms and intensive care units rely heavily on controlled gas systems for patients, including specialized delivery and holding systems, piping, monitoring and computerized control mechanisms. The electronics industry uses special gas systems for computer "wafer" manufacturing – "clean rooms." "Wafer" manufacturing also occurs in totally controlled atmosphere chambers containing specialized gases to reduce contamination of the product.

8.8.20.1 Application Areas. Controlled atmospheres may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	

8.8.20.2 Commercial Applications

- Hospitals and medical facilities

8.8.20.3 Potential Crossover Adaptations

- Proactive construction of a "controlled atmosphere" room or area for critical internal operations, such as base or facility's operational command center or information systems center.
- Separate controlled atmosphere rooms could be used continuing protective centers or as controlled space in which to decontaminate personnel or equipment
- A room or area for personnel and personal or small equipment decontamination.
- Personnel enter (with contaminated personal gear or equipment) for detoxification or use areas as a holding room while an external decontamination occurs.
- Personnel decontaminated in such a setting could perform with less limitation on activity (using masks instead of protective suits, for example).

8.8.21 Overpressure Positive Air Pressure

8.8.21.1 Application Areas. Controlled atmospheres may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	✓

8.8.21.2 Commercial Applications

- British Navy

8.8.21.3 Potential Crossover Adaptations

- Positive air pressure protection of the interior of buildings or vehicle from CB agents during attack

8.8.22 Vapor Cloud Release/Explosion Open Atmosphere Accidents

Chemical industry R&D efforts are exploring mitigation of open atmosphere accidents. This initiative focuses on proactive decontamination of the vapor cloud before it migrates or causes an explosion. Theory is based on advanced sensor development & a more sophisticated monitoring capability. Once the release is detected, advanced technology should be used to mitigate:

- Counter-release of bioremediation agent or chemical to treat in atmosphere
- Use of mechanical technique such as low frequency electrical discharge or regenerative thermal oxidation
- Meteorological methods to contain the vapor cloud so that it does not migrate off site

8.8.22.1 Application Areas. Controlled atmospheres may be used for the following CB decontamination activities.

Functional Area	Applicable for Use
Skin and Personal Equipment Decon	✓
Exterior Equipment Decon	✓
Sensitive Equipment Decon	✓
Interior Equipment Decon	✓
Large Area Decon	✓

8.8.22.2 Commercial Applications

- Atmospheric release of volatile and/or toxic substances is a major cause of explosions & fires at petrochemical facilities as well as migration of these substances over populated areas.
- Commercial decontamination technologies are designed to:

  1) Reduce exposure of operating staff & general population.
  2) Salvage civil housing, equipment & materials for reuse.

3) Salvage facility equipment & materials for reuse.
4) Reduce the volume of equipment & materials requiring disposal.
5) Restore the site & facility, or parts of them, to an unrestricted use condition.

- Current procedures, with exception of risk assessment for facility design to minimize blast damage, are reactive
- Seal-off site & areas of vapor cloud migration with "shelter-in-place" or evacuation for civil population
- Protective equipment for facility workers
- Deal with clean-up/decontamination after vapor cloud has settled on the ground
- Medical treatment for exposed populations

8.8.22.3 Potential Crossover Adaptations

- Monitoring to detect a vapor-based attack with immediate & automatic counter measures minimizing need for reactive clean up
- Meteorological technology to contain vapor cloud migration so that area of decontamination is minimized

8.9 Decontamination Tool Kit

The technologies identified as potential crossovers into military decontamination applications were subject to another level of analysis. At this level, the component technologies were structured against decontamination technical employment and possible decontamination events to construct a decontamination tool kit, which could be available to emergency response teams or for long-term remediation of a target. Table 8.3 summarizes the characteristics of the decontamination tool kit.

TABLE 8.3
DECONTAMINATION TOOL KIT

	Decontamination Application Areas			
Tool Kit	Skin and Personal Equipment	Sensitive/Exterior Equipment	Equipment/Exterior	Large Area
Barrier Tools				
Protective Lotion/Skin Barriers	X			
Filtration	X	X	X	X
Masks	X			
HVAC Systems		X	X	X
Water Systems	X	X	X	X
Equipment		X	X	
Protective Clothing	X			
Special Gas Atmospheres	X	X	X	
Over Pressure/Positive Air Pressure	X	X	X	
Prevention Tools				
Oral Vaccines	X			
Oral Antidotes	X			
Ultraviolet Purification	X	X	X	
Phytostabilization	X	X	X	X
Embedded or Protective Neutralizing/Coating				

TABLE 8.3 DECONTAMINATION TOOL KIT				
Tool Kit	**Decontamination Application Areas**			
	Skin and Personal Equipment	**Sensitive/Exterior Equipment**	**Equipment/ Exterior**	**Large Area**
Tools				
Embedded Chemicals		X	X	X
Embedded Biological Agents	X	X	X	X
Chemical Neutralizers	X	X	X	X
Biological Neutralizers	X	X	X	X
Paints and Coatings		X	X	
Silicon Elastomers			X	
Immediate Remedial Tools In Place/No Residue				
Vapor Cloud/Counter Release	X	X	X	X
Rinsing	X	X	X	X
Freeze Dried Enzymes	X		X	X
Cryogenic – Dry Ice Pellets		X	X	X
Ultrasonic		X	X	
Robotics – Remote Techniques		X	X	X
Washing/Solution	X	X	X	X
Aqueous	X	X	X	X
Semi/Non Aqueous	X	X	X	X
Water Dispersible Double Packaging Medicines/Neutralizers	X	X	X	
Oxidation	X	X	X	X
Ozone	X	X	X	X
Bleaches/Chlorine	X	X	X	
Robotics – Remote Techniques		X	X	X
Microbiological Degradation			X	X
Microbial Degradation			X	X
Gas and Foam Sprays		X	X	X
Biocatalytic Enzymes		X	X	X
Chemical Neutralizers		X	X	
Inert Gas Lamps		X	X	
Scabbling				X
Ionized Radiation		X	X	X
Immediate Remediation Tools in Place with Residue				
Water or Water & Surfactant Rinsing Washing, Pressure, Heat	X	X	X	X
High Pressure Spray			X	X
Spray/Immersion		X	X	X
Ultrasonic Cleaning	X	X	X	X
Emulsions / Microemulsions		X	X	
Water Based		X	X	
Chemical Based		X	X	

TABLE 8.3 DECONTAMINATION TOOL KIT				
	Decontamination Application Areas			
Tool Kit	Skin and Personal Equipment	Sensitive/Exterior Equipment	Equipment/ Exterior	Large Area
Supercritical Fluids		X	X	
Laser Ablation		X	X	
Plasma Cleaning		X		
Incineration				X
Deferred On-Site Residual Treatment Tools				
Microbiological Biodegradation				X
Microbial Biodegradation				X
Anaerobic Biodegradation				X
Biofilter/Slurry				X
Phytoextraction				X
Thermal Desorption				X
Rhizofiltration				X
Permeable Reaction Wall				X
Solvate Electron Technology				X
Electron Beam Accelerator				X

8.10 Integrated System Concepts

This section integrates the potential technology applications delineated in Section 8.8 with the Decontamination Tool Kit (Table 8.3), correlating both with the assumed target defined in Table 8.2. This part of the report considers technology differently than the other sections. Rather than a one to one correlation to the crossover technologies, the integrated system concept categorizes sets of information into separate but integrated systems with components drawn from all sources. Therefore, the integrated systems concepts are the most creative set of "Out-of-the-Box" ideas. Likewise, these concepts do not have a direct relationship to any identified technology or to any single records within the "Out-of-the-Box" database. Instead, these concepts are derived in a free form of thinking and are often presented in a more theoretical idiom.

The Integrated Systems Concepts and the Tool Kit use the same categories:

- Prevention. Systems that intervene proactively to preclude delivery of contaminants to the site. The techniques described assume the requirement to decontaminate the delivery mechanism at the point of interception; thus preventing contamination of the site or any civilian or other areas outside our primary wide area decontamination target.

- Minimization. Systems that minimize the impact of contamination after delivery. These systems act to decontaminate as near as possible to the points of entry or contamination and in most cases are activated automatically.

- Decontamination without Residue (short and long term). Systems that decontaminate in such a manner as to eliminate most, if not all, residual contamination at the various sites.

- Decontamination with Residue (short and long term). Systems that, as a last resort, decontaminate to levels below thresholds that permit restoration of operational status, but leave residues of contamination. These residues must eventually be dealt with either at the site or at some remote (usually centralized) decontamination treatment site. The decontamination treatment site may not be within the site that is being decontaminated.

The following table lists the concepts by title. Subsequent paragraphs provide descriptions of each.

TABLE 8.4 SUMMARY OF INTEGRATED SYSTEM CONCEPTS	
PREVENT: Preclude delivery via interception	101: Laser/ UV Light Shield 102: Controlled Vapors: Open Atmosphere
MINIMIZE: Reduce impact of delivery on target specific basis	201: Interactive Filtration 202: Over Pressured Atmosphere Buildings/ Rooms 203: Automatic Release/Embedded Capsules with Neutralizers 204: Automatic Neutralizing Coatings/Packaging 205: Phytoremediation (Irrigation and Plants)
DECON: NO RESIDUE- SHORT TERM: Remove contamination in place within hours	301: Controlled Vapors: Inflatable Buildings 302: Controlled Vapors: Buildings Interiors & Rooms 303: Interactive Rinsing: Exterior Surfaces 305: Rhyzofiltration (Irrigation and Plants)
DECON: NO RESIDUE - LONG TERM: Remove contamination in place within days or longer	401: Phytostabilization 402: Other Bioremediation
DECON: RESIDUE- SHORT/LONG TERM: Restore operational capability in place within hours	501: Rinsing with Water/ Surfactants 502: Thermal Treatment 503: Contaminated Residue Storage

8.10.1 <u>Integrated Concept 101: Laser/Ultraviolet Light Shield</u>

This concept goes beyond near term adaptability. It is included because the concept surfaced during the analysis, and it appears to be highly novel. If feasible, this concept can provide a prevention mechanism that would eliminate or minimize the need for reactive measures to decontaminate a site after CB agents actually landed on the surfaces, structures and personnel.

The concept is to develop and install a light shield system consisting of laser beams and mirrors. The reflected high intensity lasers and mirror systems can be positioned to provide coverage of an area. Light has been used for some time in the food processing and the electronics industries to decontaminate objects or atmospheres. In addition to acting as a neutralizing shield, it could also deflect incoming projectiles or missiles or trigger counter measures. The shield would operate automatically, impacting and neutralizing incoming CB agents upon arrival or release. Another alternative would be to use the laser technology in combination with Concept 102, which is a counter vapor cloud as described below.

The laser/mirror shield could cover all or a considerable portion of a site. To protect against incoming projectiles or releases from the ground or under the laser "ceiling", UV light beams (not harmful to personnel as laser beams) could be installed to create perpendicular "walls" around the ceiling, effectively shielding the entire enclosed space. The UV light beams, used in the food purification and water treatment industries would provide similar neutralization protection.

TABLE 8.35 INTEGRATED SYSTEM CONCEPT 101: LASER/UV LIGHT SHIELD					
PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
✓	✓	ALL	ALL	ALL	ALL

8.10.2 Integrated Concept 102: Controlled Vapors: Open Atmosphere

The basic idea of "controlled vapors" is common to several Integrated System Concepts, which vary significantly based upon the context of their employment. However, the core idea is built around the proposition that it is possible to develop special vapors using selected mixes of gases whose densities permit controlled suspension and dissipation times. In addition, these "vapor solutions" have or carry molecular structures that are embedded with micro encapsulated sensors and related neutralizing agents. When a contaminant passes through or is enveloped by this controlled vapor, the sensors automatically trigger release of the neutralizers at a rate that achieves total decontamination or significantly reduced contamination. Wherever the term "controlled vapors" is used in the following integrated system concepts, this principle is encompassed.

In this particular application, the controlled vapor is dispensed into the open atmosphere over all or part of the wide area decontamination target. The system involves pressurized storage tanks of the gas based mixtures, when released into the atmosphere they will form a vapor cloud of needed composition over a designated area. These storage tanks are attached to fixed or mobile sprayers that eject the mixtures, which in turn vaporize upon contact with the air. One major limitation to this system is that prevailing weather conditions have to be within acceptable limits (i.e., wind, temperature and rainfall). The wind and rainfall are the most non-controllable and non-predictable variables.

The scope of coverage will ideally encompass the entire zone threatened by the incoming delivery vehicle; i.e. aircraft, missile, or other delivery mechanisms. However, if this is not feasible, priority zones can be established in advance.

A "triggering device" will control correctly timed dispensing that can be activated for a specified time based upon the early warning system signaling the attack. The objective is to saturate the atmosphere with this vapor cloud as close as possible to the time the contaminants are released. The vapor cloud should hug the ground and extend as far upward as is feasible. Any release of agents in the air will have to pass through the neutralizing vapor cloud. Conversely, releases that occur upon ground impact are immediately dispersed into the vapor cloud. The probability is that the effective percentage of decontamination will be directly related to the altitude or other variables dictating exposure time before the contaminants escape the vapor cloud.

The large-scale nature of this concept requires significant specialized and pre-positioned equipment. This investment is justified by the degree to which operational readiness and personnel safety is less compromised and subsequent requirements for post-delivery decontamination are substantially reduced.

A variation on this approach is to attempt to force the cloud to migrate to a specified treatment site so that environmental remediation of any residue will be both minimal and contained to a limited or non-operational area. On specific sites, meteorological expertise may help to identify techniques to accomplish this deflection.

For the long term, an open atmosphere treatment plan could be combined with base placement and design. Such planning could take advantage of meteorological conditions combined to force migration of the vapor cloud to a specified area, thus minimizing the need or timing of remediation after the attack.

TABLE 8.6 INTEGRATED SYSTEM CONCEPT 102: CONTROLLED VAPORS: OPEN ATMOSPHERE					
PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
✓	✓	ALL	ALL	ALL	ALL

8.10.3 Integrated System Concept 201: Interactive Filtration

Filtration is an established technology, but advance microfiltration technology provides some "Out-of-the-Box" concepts. Standard membrane and reverse osmosis filters can protect personnel, operational areas and water supply. They can be used as long as they are effective. These filtration capabilities have been refined to parts per billion and parts per trillion, decontamination levels not attained by standard filtration. Traditionally, filters are passive. They absorb particulates or organisms of specified size out of air, gases or liquid streams that flow through the filters. Advance filtration of microparticulates moves well beyond these techniques.

Examples of highly effective micro- or ultra- filtration of micro-particulates, chemicals, bacteria, viruses, and metal contaminants as well as separation of special gases occurs in the electronics, biochemical, medical, pharmaceutical and industrial gases industries, among others. These materials and techniques ensure that the trapped contaminant is not exposed to the surrounding atmosphere of whatever nature or is separated into a holding area that is self-contained. Advanced filters used in medical research and medications, use polymer nanotubes to separate molecules or isolate bacteria or viruses. Controlled chamber filtration using polymer nanotubes with controlled gas atmospheres are employed in electronic chip manufacturing. They assist in etching circuits on silicon, or to enclose atmospheres to prevent contamination. Other advances in filtration techniques also go beyond the traditional barrier filter, using zeolites or manufactured polymeric materials to trap particulates within the molecular structure of the filter material, not just on its surface.

Such advances in molecular structures may now be combinable with embedded or encapsulated sensors and neutralizers in such manner as to make them more than barriers. They can become interactive, real time decontaminating systems; i.e. they do not just capture the contaminants, they neutralize them - eliminating any additional downstream handling risks involved (such as the risks that filters have when they become saturated with contaminants and organisms could "escape"). This concept is conceptually similar to the above controlled vapor concept.

Therefore, the "Out-of-the-Box" filtration systems would use complex materials to provide balanced combinations of high purity "strainers" with super absorption and on-line decontamination features built in. Combining nanofiltration with decontaminants encapsulated in the structures of the filtering materials would guarantee protective filtration/neutralization that would not have to be treated, renewed, or removed during an operational period concurrent with or immediately after an attack.

A potential extension of the concept could also have the filter act as the dispenser of decontaminants embedded within the filter or as a triggering device for automatic start up of a related system designed to inject controlled vapors into the room, compartment or other area being filtered.

Appropriate designs can employ these "next generation" filters to prevent or minimize the contamination that can reach the targets with which we are concerned (Table 8.7).

TABLE 8.7
I. INTEGRATED SYSTEM CONCEPT 201: INTERACTIVE FILTERS

PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
✓	✓	1. Operating Personnel 2. Personal Tools & Weapons 3. Drinking Water 4. Personnel in Transit 5. Food & Medicines 6. Clothing	1. Selective applications on equipment requiring air, gas or liquid intakes to protect internal components - such as operator compartments and motors	Many types of interior equipment have comparable functional components as described for exterior equipment	Enclosed Critical Operations Centers

8.10.4 Integrated System Concept 202: Over Pressured Atmosphere: Buildings/Rooms

Any CB agent that is not introduced directly into a closed space must penetrate such space at some infusion point. The ability to make the penetration is dependent upon "flowing" in from outside. The rate and ease of such "in-flows" is directly related to the comparative pressures outside and inside the space being penetrated. From this principle, the concept of over pressure has emerged. If the pressure within the targeted space can be maintained at sufficient levels, this acts as a barrier (a form of atmospheric packaging) that precludes penetration by airborne CB agents.

There are practical limits to extensive deployment of this concept in the military environment. The space being protected must be sufficiently "tight" to permit pressurization. In addition, the capability to keep the pressure up requires some outside mechanical device. The protective pressure shield would be dependent upon the non-interrupted operation of these devices. Still, such capabilities clearly exist to some degree; pressurized aircraft compartments offer a ready example.

Perhaps portable "pressure generators" could be included on enclosed vehicles - such as rail cars and trucks in much the same manner refrigeration is provided. This could protect all interior cargo during shipment or storage within such units, as well as keeping the interiors of the units themselves "clean". This same idea could be adapted for installation on bulk containers into which containerized cargo is packed for transport - ocean, rail, air or road. The container then carries its own pressure generator as a permanent fixture. In long transport cases, such as ocean shipments, the pressure engine could be left off until danger zones are approached. Synchronized remote triggering devices could then start and retain the over pressure condition only for the time needed. In these cases, the pressurizing equipment is largely independent of centralized energy systems. The ability to use the system only when needed would decrease the size and cost of fuel for the pressure engine.

These concepts of low cost, readily available pressure engines (portable or installed) that can be triggered only under needed conditions lends greater potential to these ideas being applied to any enclosed space which can meet the conditions of pressure containment. When one couples this with commercial systems for spraying foam insulation into or onto walls of buildings, it seems feasible to insulate many such spaces in buildings and transport equipment to meet these pressure containment requirements.

In industry, controlled interior atmospheres units rely heavily on specialized, controlled gas systems, including specially designed delivery and holding systems, piping, monitoring and computerized sensing and control mechanisms. Hospitals have such systems for intensive care and operating rooms, as well as special units for patients with breathing, heart and other conditions needing special gas atmospheres. The chemical, airline, pharmaceutical, electronics and other industries have controlled atmospheric areas or vehicles for personal safety, environmental control, comfort, and product quality.

In the proactive mode, a room or space is sealed by use of by positive atmospheric pressure to prevent contamination from entering. Such a building, room or space necessarily would be constructed of impermeable materials or could utilize filtration as discussed in Concept 201. Should the space be penetrated, the special gases system already in place for overpressure could be adapted to inject decontaminating atmosphere without additional preparation time. The latter event is treated in a later concept.

TABLE 8.8
INTEGRATED SYSTEMS CONCEPT 202: Over Pressured Atmosphere Buildings/Rooms

PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
✓	✓	1. Operating Personnel		All equipment in a protected room	1. Personnel Barracks 2. Recreation & Mess Facilities 3. Administration Buildings 4. Warehouses 5. Repair Facilities

8.10.5 Integrated System Concept 203: Automatic Release /Embedded Capsules with Neutralizers

CB sensing capability to back up military surveillance, radar and similar systems is assumed in this section. If such sensing is not available, it must be included for some aspects of this concept to be operational. If possible such capability should include sophisticated sensing devices that automatically trigger a warning when CB agents are above or arrive on a site.

The pharmaceutical, medical research, food service and industrial cleaning industries encapsulate various chemicals and biological entities for separation, study or to be released upon contact with another CB substance or entity. These technologies are the basis for a proactive strategy to apply coatings or embed surfaces with counteracting chemicals to neutralize contaminating chemical agents or to act as biocidal substances to kill or neutralize pathogens. The encapsulation has been refined to the level of the molecule, bacteria and virus, using microfiltration, nanotubes and other procedures to capture or hold minute amounts in suspension.

Any selected solid surface or substrate can be embedded or coated with such neutralizing chemicals or encapsulated organisms. The preferred option for release of the counteractive decontaminant is an automatic chemical reaction. If this is not possible, a sensor may be structured to release the neutralizing agent upon an electrical or electronic signal.

Ideally, multiple chemicals to counteract several possible incoming CB agents would be available and utilized. However, if information about incoming agents were available, the embedded chemicals could be simplified and targeted to neutralize only anticipated incoming agents. If the "embedding sprayers" are made as portable units, this concept could be applied to transit cargo and transportation ships or vehicles as well as to exterior surfaces of buildings, runways, outside storage grounds and other related targets.

TABLE 8.9
INTEGRATED SYSTEM CONCEPT 203: Automatic Release/ Embedded Capsules with Neutralizers

PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
✓	✓	1. Clothing 2. Personal Equipment 3. Bedding and Other Items in Which Direct Contact or Breathing Occurs	1. Vehicles 2. Cargo Handling Equipment & Supplies 3, Ships 4. Aircraft 5. Railway Rolling Stock	Any interior equipment whose operations would not be hampered by such embedded capsules and whose surface materials lend themselves to such treatment	1. Open Storage 2. Warehouses 3. Port Facilities 4. Repair Facilities 5. Rail Yards 6. Barracks 7. Admin Buildings 8. Roads 9. Mess Facilities 10. Fixed Weapons Systems

8.10.6 Integrated System Concept 204: Automatic Neutralizing Coatings/Packaging

The paint and coatings industry has developed various protective coatings for surfaces, many of which are biocidal or chemically neutralizing. Many are used in the food processing and service industries, hospitals and child care centers. Neutralizing coatings have a variety of other uses, such as protecting ship's hulls from "fouling" by barnacles and shellfish attaching to underwater surfaces. Adapting this technology to proactively coat surfaces, especially external surfaces or critical interior surfaces, would reduce initial contamination and minimize the need for active clean up and remediation.

Some coating materials are much more sophisticated than typical paint, using such material as silicon elastomers which can neutralize, withstand extreme heat and are easily moldable into many shapes or types of coverings of varying thickness. Silicon elastomer products are used in the space program, in heavy industry and as biocidal coating or for medical devices.

The cosmetics industry has developed a product that provides skin protection against most chemicals including common household and workplace detergents, solvents, paint thinners, pesticides and other toxic threats to the skin. Although formulated to naturally soften hands like the best skin lotions, the product was originally developed to create a protective shield or barrier for the skin. Assimilated into the skins' outer layer, the product forms a web between the dead skin cells, resulting in a one way barrier which prevents most irritants and toxins from penetrating the skin. It seems feasible to adapt this technique to military decontamination.

The packaging industry has developed a water-dispersible film for packaging aqueous products without the film disintegrating from the inside. The material enables paired bags containing incompatible products to be stored in the same packaging. This approach is used with pharmaceuticals and in biochemical research. Researchers are adapting the technology to decontamination of insecticides and chemical agents such as nerve gas. Such packaging could also be used to cover and provide neutralization of sensitive equipment or in situations where water is contaminated. It could also be used to store decontaminants on site for use when an attack occurs. Short lived biological decontaminants could be stored together but separated, and mixed upon attack for activation at the right moment.

TABLE 8.9 INTEGRATED SYSTEM CONCEPT 204: Automatic Neutralizing Coatings					
PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
✓	✓		1. Vehicles 2. Cargo Handling Equipment & Supplies 3. Ships 4. Aircraft 5. Railway Rolling Stock		1. Open Storage 2. Warehouses 3. Port Facilities 4. Repair Facilities 5. Rail Yards 6. Barracks 7. Admin. Buildings 8. Roads 9. Mess Facilities 10. Fixed Weapons Systems

8.10.7 Integrated System Concept 205: Phytoremediation (Irrigation and Plants)

Phytomediation is a form of bioremediation (the generic term) involving plants and describes a group of bioremediation technologies. Phytoremediation is the engineered use of green plants to remove, contain or render harmless a variety of organic compounds. The process begins with absorption of the chemical by the plant. The use of microbes to degrade chemicals in soil or water has become a major industry in recent decades. Of the several types of phytoremediation, some are effective with certain chemicals within hours, rather than days or weeks. The plants trap the chemical and even if not neutralized immediately it is out of the operations substrate.

Work areas, runways or dock facilities could be designed to have runoff directed to the side where appropriate bioremedial plants would grow or a channel would direct the runoff to the planted area. The liquid runoff would need no further immediate treatment.

In studies with TNT, enzymes within the plant and on the root surface reduced the chemical molecules into amines, thereby neutralizing the toxicity. Glucose and other molecules then bound the newly formed molecules into the plant's cellular structure. The chemicals eventually help the plant build its cell walls. The first step of the lengthy process occurs within hours and the entire process leaves no runoff. Tests have found the process particularly effective with various organic chemicals. The process has been refined to preclude live microbes from being transported and used for the process. Enzymes have been extracted from microbial cells and the enzymatic compounds are being genetically engineered to decontaminate a broad range or combination of toxic chemicals.

TABLE 8.10 INTEGRATED SYSTEM CONCEPT 205: Phytoremediation (Irrigation and Plants)					
PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
✓	✓				1. Soil & Ground 2. Ground Water 3. Surface Water 4. Marine Environment

8.10.8 Integrated System Concept 301: Controlled Vapors: Inflatable Buildings

The core concept of Controlled Vapors was described above. This is a special adaptation of the concept for infusion into atmospheres contained with inflatable buildings. If a site or a portion of a site is contaminated, the immediate need is to conduct decontamination activities. In forward locations, a portable but specially designed decontamination structure is a preferred option. Such an inflatable, collapsible structure could be easily stored, moved and adapted to one or more forward logistics centers. The inflatable building would be equipped so that a controlled vapor could be used as the decontaminant. If desired different sized inflatable buildings could be available for simultaneous decontamination of personnel, small equipment, vehicles or larger equipment, such as loaders, aircraft or railcars.

The basic concept is that the inflatable building provides a mechanism for portability and/or quasi-temporary creation of a space that can then become a controlled environment. The major needed refinement would be to have the "building" tight enough. Specialized means of attaching the materials to either hardened or ground surfaces should suffice. These "buildings" could be tailored to various functions in which functionally specific equipment would be provided for; shower rooms dispensing decontaminates through vapor systems dispensed through the nozzles, "tunnels" through which aircraft or transport equipment could be run for vapor cloud decontamination or for specialized rinsing. In the cases where contaminated residuals are left, the "building system" could include runoff channels that would collect the residuals into on the spot treatment points or into containers for safe transport to a centralized treatment point - on or off the wide area decontamination site.

TABLE 8.11 INTEGRATED SYSTEM CONCEPT 301: Controlled Vapors: Inflatable Buildings					
PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
✓	✓	1. Operating Personnel 2. Deploying Force Personnel 3. Personal Tools & weapons 4. Clothing	1. Vehicles 2. Material handling Equipment & Supplies 3. Aircraft 4. Cargo		

8.10.9 Integrated System Concept 302: Controlled Vapors: Buildings Interiors & Rooms

As discussed in related Concepts 102 and 301 above, controlled vapors containing embedded sensing and neutralizing capability are an effective decontaminating technology, leaving little or no residue and acting quickly on surfaces as well as any exposed crevices or openings into material. This concept is based on the same ideas. The basic difference is that the building is of a more traditional nature; i.e., fixed in place and with rigid exterior walls.

If the site and its facilities are of such duration and enough lead-time is provided, a building or room prepared for such decontamination activity is preferred over the inflatable building discussed in Concept 301 above. Fixed piping, connections with a gas supply and monitoring devices could be prepared in advance for use immediately upon attack.

Hospitals, electronics manufacturers, civil defense agencies, chemical and industrial gas companies have applications of controlled vapor systems and structures. All controlled vapor units rely heavily on specialized delivery and holding systems, piping, monitoring and computerized sensing and control mechanisms. Decontamination using encapsulated neutralizers and gases, as discussed in Concepts 102 and 301 above, would apply.

TABLE 8.12 INTEGRATED SYSTEM CONCEPT 302: Controlled Vapors: Buildings Interiors & Rooms					
PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
✓	✓	1. Operating Personnel 2. Deploying Force Personnel 3. Personal Tools & weapons 4. Clothing	1. Vehicles 2. Material handling Equipment & Supplies 3. Aircraft 4. Cargo		

8.10.10 Integrated System Concept 303: Interactive Rinsing: Exterior Surfaces

Industrial cleaning includes aqueous, emulsion-based and advanced cleaning technologies. A wide variety of industrial cleaning processes are currently in use by the military. Additional cleaning processes could be readily adapted. The most commonly used technologies leave residue. However, in recent years due to competition, environmental concerns or technological advances, techniques that leave little or now residue of a toxic nature are available. The concept expressed here is to adopt or adapt cleaning technology which is effective, quick, needs limited application time, and produces little or no residue.

Exterior surfaces of equipment whether sensitive, interior or exterior can be treated with biocidal or neutralizing chemical washes or sprays. Depending upon the sensitivity or location of equipment, these can be applied by rinsing, sprays, through ultrasonic washing coupled with an aqueous fluid or water/surfactant/neutralizer application. Ozone washing occurs in cold water, requires no on-site storage, and is accomplished using portable washers that leave no residue. The life span of Ozone is approximately 20 minutes and then it degrades to oxygen, therefore leaving no chemical residue. Ozone is 3000 times more effective than chlorine in disinfecting biological agents. It may be used to:

a. Purify drinking water, food or consumables
b. Wash contaminated cloth and clothing;
c. Clean recirculating water systems, thus avoiding a requirement for a outside water supply
d. Clean equipment, vehicles and surfaces, if such cleaning can be done in a 20-minute time frame.

Chemical-based emulsions based on hypochlorites or microemulsions of a combination of neutralizing chemicals are also available. Advanced cleaning techniques include supercritical cleaning, a process which combines gas under pressure near the supercritical state to impact a surface. They are non-aqueous and more environmentally benign.

One of the most adaptable is dry ice (carbon dioxide) pellet cleaning of such surfaces. This cryogenic process, akin to sandblasting, provides ablation of the surface, but does so with few of the disadvantages of sandblasting. The frozen pellets, crystals, or "snow" are shot from a high-pressure nozzle. The pellets remove the contaminant and then dissolve in the atmosphere as their temperature rises. Minimum residue remains. Pellet size, hardness and velocity of the nozzle blast can be altered for a range of cleaning needs. The approach would be effective on solid surfaces such as building walls, concrete or asphalt work or loading areas or runways. Large throughput containers if properly covered could be treated in a similar manner.

Dry ice pellets, other supercritical cleaning approaches use alkyl or other bromide blends, and laser ablation are also used in precision cleaning of sensitive equipment such as gyroscopes, medical implants and semiconductors.

By adapting these advanced technologies into the wide area decontamination context, an effective form of interactive rinsing can be introduced. This rinsing will significantly reduce or eliminate residual contaminated runoff that must be dealt with before full operational status is restored.

TABLE 8.13 INTEGRATED SYSTEM CONCEPT 303: Interactive Rinsing: Exterior Surfaces					
PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
	✓		All	All	1. All Buildings

8.10.11 Integrated System Concept 305: Rhyzofiltration (Irrigation and Plants)

Rhyzofiltration is a bioremedial process trapping chemicals from contaminated water into the cells and root structure of plants containing microbes or genetically engineered enzymes, which over time neutralize the contaminant. Often a polluted stream of water is pumped through a trough planted with accumulator plants. Several passes may need to occur before the water is clean enough to be discharged into the water or sewage system. The trapping process renders the decontaminant temporarily trapped and out of the way, but the complete process of cleaning the water takes days or weeks depending on the contaminant and the type of plants. Such a system could be included in a site in order to provide an immediate outlet for contaminated runoff that later would need no further disposal.

TABLE 8.14 INTEGRATED SYSTEMS CONCEPT 305: Rhyzofiltration (Irrigation and Plants)					
PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
✓	✓				1. Soil 2. Ground Water 3. Run off 4. Marine Environment

8.10.12 Integrated System Concept 401: Phytostabilization

Phytostabilization, a plant based process, is a form of phytoremediation that provides a long-term solution to the residue problem. The process collects contaminating chemicals in plant root systems. It eliminates the chemical from the soil and retains them in the plant. There is no leaching, migration of chemicals off site or other exposure. This process takes months but is self-activating and also provides a ground cover for the contaminated soil. In industry it is used primarily to remove toxic metals from soil.

With proper advance planning and site design, this technology, if adaptable to chemical agents, could be combined with other bioremedial approaches to provide an array of short term entrapment, neutralizing and long term remediation on site without significant time and effort by personnel.

TABLE 8.15 INTEGRATED SYSTEM CONCEPT 401 PYTOSTABILIZATION					
PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
✓	✓				1. Soil 2. Ground Water 3. Run off 4. Marine Environment

8.10.13 Integrated System Concept 402: Other Bioremediation

Several bioremediation approaches not previously mentioned in the integrated system concepts are available. All include the treatment of contaminants by biological processes either through the use of microbes or engineered enzymes that act to decontaminate. They include: biofilters for treatment of airborne contaminants escaping from soil- or water-based contamination; bioreactors for treating contaminated water or sludge usually in a contained area for interaction with the biological decontaminates; fixed film bioreactors and powdered activated charcoal treatment.

These bioremediation approaches may hold promise for medium to long range treatment of CB agents. Each provides little or no residue upon completion of the process.

TABLE 8.16 INTEGRATED SYSTEM CONCEPT 402 OTHER BIOREMEDIATION					
PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
✓	✓				1. Soil 2. Ground Water 3. Run off 4. Marine Environment

8.10.14 Integrated System Concept 501: Rinsing with Water/Surfactants

Surfactants increase the effectiveness of water rinsing. Rinsing contaminated surfaces or areas with water and surfactants is not an "Out-of-the-Box" concept. Interactive rinsing with neutralizers is recommended in Concept 303. It is also recommended that residue, if any, be directed to plants that use biological processes to trap or decontaminate the agents. If standard rinsing techniques are used and residue remains, it must be collected or channeled away from the operations area. The following technology regarding absorption of the runoff may be helpful in restoring the affected area to an operational level sooner.

Highly absorbent materials are now available. Several are made of material that includes polymer chains for trapping contaminants. One is a sponge-like surface with nanopores that soak up contaminants from water and aqueous solutions. Prior to rinsing, the area should be covered with super-absorbent materials. Upon completion of the rinse, a tarp, channel or blanket could be folded, dragged or lifted into a vehicle for transport to a secure area for later treatment by one of the techniques for minimal residue described early in this concept section. The sponge-like material could also be covered with a sealant for transport off site.

TABLE 8.17 INTEGRATED SYSTEM CONCEPT 501: RINSING WITH WATER / SURFACTANTS					
PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
	✓				1. Soil 2. Ground Water 3. Run off 4. Marine Environment

8.10.15 Integrated System Concept 502 Thermal Treatment

There are a great number of thermal processes for disposing of contaminants. Most of the processes are not "Out-of-the-Box" for the commercial world, but may not figure into current site-based decontamination strategy. The most common thermal processes used by industry are:

a. Incineration - which is burning in some ambient atmosphere.
b. Thermal desorption - which uses heat to decontaminate hazardous chemicals in contaminated soil or liquids. This can be performed either on or off site.
c. Microwave heating - which is also used for contaminated liquids, solids, soils and surfaces.
d. Steam separation for decomposition of industrial contaminants.
e. Pyrolysis - where extreme heat causes the material to change chemical composition without burning.

Incineration is a standard technology but creates hazardous emissions and waste. Any improvements should aim at greater efficiencies, higher oxidation rates and seek to customize systems by blending gases related to these objectives, functional need and the given type of material to be incinerated.

Preferable technologies would be those that are less contaminating than incineration. Microwave heating and thermal desorption are discussed here, pyrolysis in Concept 503 below.

Microwave heating is widely used in industry, not only as a preliminary step in many food processing procedures, but also in the following areas:

a. Sterilization for pharmaceutical manufacturing
b. Radiation curing of paints and coatings
c. Steel manufacturing

d. Chlorinating of liquids
e. Decomposing minerals for metal ore separation in mining
f. Treating contaminated concrete slabs or contaminated solid or liquid waste.

Portable microwave heating devices are already available. They could be used to decontaminate a variety of waste, liquids, consumables, surfaces or solids. Use of this familiar technology off site, or even for immediate on site decontamination, is feasible since it is portable, economic, and easy to use.

Thermal desorption can be low (90-320 degrees C) or high (320-560 degrees C) temperature. In either case, thermal desorption volatilizes water and organics, which are transported by a carrier gas or vacuum system to a gas treatment system. All contaminants will be volatilized but not all may be oxidized. Off gases can be routed to an after burner where they are destroyed. Such a system would be appropriate for an off site decontamination center.

TABLE 8.19 INTEGRATED SYSTEM CONCEPT 502: THERMAL TREATMENT					
PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
	✓				1. Soil 2. Ground Water 3. Run off 4. Solid Waste

8.10.16 Integrated System Concept 503: Contaminated Residue Storage

On-Site Storage: Storage on-site and transportation for storage or treatment off site are options for contaminated soil, water or equipment.

Levels of storage exist for contaminates that cannot be neutralized. The best is one that completely envelops the contaminant so temporary storage on-site is not hazardous to personnel and does not interfere with operations. Preferably this would involve some technology, such as nanosponges or blankets as discussed in Concept 402.

Once permanent decontamination or transport off site for similar treatment becomes feasible, the temporary storage technique should allow direct transition to the transport mode without any intermediate step or exposure for personnel or the site during this transition.

Transport Off-site for Storage or Treatment: Loading for transport, as mentioned above, should occur without repeat exposure to the contaminant. Transport could be to an off site storage area, but preferably would end at a treatment center using one of several technologies that do not leave any residue.

A portable pyrolysis unit brought in by cargo plane, rail, or ship would be one innovative way to deal with long-term contaminating residue. Pyrolysis, using extreme heat in an enclosed unit, sometimes generated by laser or mixed with chemicals, creates thermal decomposition of contaminating chemicals or biological agents without burning. It leaves no residue except for an inert charcoal. It is used widely for decomposition of hazardous waste (solid or sludge). With medical waste, for example, it turns biological contaminants and their containers into carbon dioxide, oxygen and inert charcoal powder.

Such a portable unit could be moved to appropriate locations on or near sites that need such services. Portable and reusable equipment would create economies and the non-residual, not burning aspects of this technology would be more favorably received by the host country compared to more intrusive, contaminating systems.

TABLE 8.20 INTEGRATED SYSTEM CONCEPT 503: CONTAMINATED RESIDUE STORAGE					
PRO-ACTIVE	RE-ACTIVE	SKIN & PERSONNEL EQUIPMENT	EQUIPMENT/EXTERIOR	SENSITIVE/INTERIOR EQUIPMENT	LARGE AREA
	✓				1. Soil 2. Water 3. Solid Waste 4. Equipment

8.11 Wide Area Decontamination Scenarios

8.11.1 Introduction

This section describes four specific contamination events with associated scenarios detailing potential responses to each threat. The events concern a military or terrorist attack on a major logistical support facility as defined in Table 8.2. The purpose of the application scenario is to provide examples of how the crossover technologies and integrated system concepts identified in this report can be utilized in decontamination toolbox and be applied against specific threats. Scenario development also provides a method to identify what the impact of decontamination technology selection will be in terms of actual protective, clean up and remediation operations. For this reason, each event considers two basic scenarios in response to the threats. One scenario assumes extensive proactive technologies utilization, the other assumes extensive reactive tools on site. We identified the following contamination events at a major logistical support facility:

E01 Atmospheric release of chemical agents over a major logistical support facility
E02 Release of biological agents at a major logistical support facility into an administrative facility's full internal environment via the heating, ventilation and air conditioning (HVAC) system
E03 Exposure of personnel at a major logistical support facility to biological agents delivered via barrack showers

8.11.2 Event E01: Atmospheric Release of Chemical Agents

8.11.2.1 Event

This event is a military or terrorist attack on a major U.S. logistical support facility. The host nation is an important ally who requested U.S. force projection. The facility is located contiguous to the host's largest metropolitan area, the national capital.

A mix of chemical agents is introduced at low altitude to the atmosphere above the facility. The weather is clear with no wind. The agents could be delivered via several different methods, which include:

a. A low flying light or military aircraft, acting on the same principle as a "crop duster", spreading a vapor cloud over the site.
b. An air blast from a missile over the site given the proper meteorological conditions.
c. A ground release from a tanker truck, or other vehicle, located near the perimeter of the facility that sprays or releases agent into the atmosphere.

Regardless of the means of delivery, the threat poses grave risk to the facility and its military mission. In this event the major problem is associated with the chemical agents settling on surfaces and entering the interior of buildings and other closed structures, posing a respiratory hazard to personnel. While, of course, the ideal for such a facility is to avoid contamination, in reality this may not be an option. Similarly, the specific requirements for large area decontamination, restoration of operations and remediation are not a straightforward listing of capabilities. Such requirements vary widely from site to site and therefore all proactive means of protection must be designed based on specific locations.

8.11.2.2 Assumptions. The major logistical support facility has the following decontamination objectives:

1) Restore the site's operational capability quickly
2) Decontaminate on-site supplies and assets quickly to reduce the disruption of supply operations
3) Render the site fully operational ASAP
4) Meet medical decontamination requirements of non-conventional casualties
5) Monitor contaminated assets before and during decontamination to ensure that chemical agents are not transported to clean areas
6) Limit the risk of decontamination personnel's exposure to the chemical agent
7) Finalize remediation efforts as required by the host country.

The "Out-of-the-Box" ideas demonstrate the ability to mitigate contaminant damage and that decontaminating a large area is technically possible if a mosaic of operational systems are available before the attack. This technology provides an opportunity to take proactive steps that reduce actual contamination and minimize the need for extensive site remediation and the handling/storage of contaminated waste. Use of advanced technology limits the need to deal with the run-off or wastes generated by decontaminate solutions. Such technology similarly provides practical options for full on-site treatment of all CB agents.

Two decontamination scenarios summarize different levels of response to the open atmosphere event. One assumes that proactive technologies are the site's foundation defense against CB threats. In this sense, the facility is hardened against attack. The other scenario assumes a soft target applying reactive, but still advanced decontamination tools. Site specific assumptions for the hardened site include:

1) Deployment of large scale contaminate sensing, monitoring and mapping systems
2) Up front planning included a full range of on-site technical capabilities that mitigate some contamination as it occurs, avoids several types of contamination almost completely, and minimizes requirements for massive clean up of the decontamination process itself
3) Technical and human assets are available on-site for instant response to the threat
4) "Super" bugs and chemicals are engineered to counter many different CB agents.

Site specific assumptions for the soft site include:

1) Deployment of large scale contaminate sensing, monitoring and mapping systems;
2) Up front planning included a limited range of reactive on-site technical capabilities with few mitigation assets
3) Advanced decontamination systems and trained human assets are not available on-site, but are located at centralized centers for reactive deployment to contamination emergencies
4) "Super" bugs and chemicals are engineered to counter many different CB agents.

These two alternatives were selected because scenarios contrasting employment of proactive technologies with application of reactive technologies clearly illustrates the impact of technology selection in terms of actual operations. In scenario E01.A, despite the attack and because proactive technology is embedded on-site, the facility suffers more limited contamination than in E01.B. Therefore, in scenario E01.A the facility requires less decontamination.

8.11.2.3 Scenarios

TABLE 8.21
WIDE AREA DECONTAMINATION SCENARIOS – EVENT E01

SCENARIO TARGETS SPECIFIC DECONTAMINATION OBJECTS	SCENARIO E01.A SITE HARDENED AGAINST CHEMICAL THREAT	SCENARIO E01.B SITE SOFT AGAINST CHEMICAL THREAT
SKIN & PERSONAL EQUIPMENT		
OPERATING PERSONNEL	Protected from most contamination because of proactive counter measures, little or no decontamination required If minimal contamination, personnel dawn masks, suits and/or protective lotion proceed to controlled vapors interior space for decontamination	Shelter in place, dawn masks and suits to remain operational If necessary, proceed to interactive neutralizing, rinsing area for decontamination. Casualties decontaminated at medical facility using bio-engineered antidotes
DEPLOYING FORCE PERSONNEL	See descriptions for operating personnel	See descriptions for operating personnel
DRINKING WATER	Not contaminated below safety thresholds, no decontamination required If minimal contamination, system of interactive filtration protects supply	Water system is shut off and water is tested. If contaminated, circulate contaminated water to bioremediation equipment for chemical neutralizing
FOOD, MEDICINE & OTHER CONSUMABLES	Not contaminated below safety thresholds, no decontamination required If minimal contamination, protected by packaging and/or interactive chemical neutralizers	Dispose of contaminated material and treat as contaminated waste Replace with uncontaminated materials
PERSONAL TOOLS & WEAPONS	Not contaminated below safety thresholds, no decontamination required If minimal contamination,	If necessary, carry to rinsing area for decontamination, run off channeled to phytoremediation area for treatment
CLOTHING	Not contaminated below safety thresholds, no decontamination required If minimal contamination, use ozone washing or other process which leaves little or no residue	If necessary, carry to rinsing area for decontamination; ozone washing or other process which leaves little or no residue Any run-off channeled to phytoremediation area for treatment

TABLE 8.21 WIDE AREA DECONTAMINATION SCENARIOS - EVENT E01		
SCENARIO TARGET'S SPECIFIC DECONTAMINATION OBJECTS	**SCENARIO E01.A: SITE HARDENED AGAINST CHEMICAL THREAT**	**SCENARIO E01.B: SITE SOFT AGAINST CHEMICAL THREAT**
EXTERIOR EQUIPMENT		
VEHICLES	Not contaminated below safety thresholds, no decontamination required If minimal contamination, automatic release capsules or neutralizers will activate	Automatic coatings, release capsules or neutralizers will activate If necessary, rinse with any run-off channeled to phytoremediation area for treatment or captured by advanced absorbent materials for removal
SHIPS & MARINE VESSELS	Not contaminated below safety thresholds, no decontamination required If minimal contamination, automatic release capsules or neutralizers will activate or overpressure for interior will be active	Neutralizing coatings on external surfaces above and below water will protect exterior Key areas are protected by overpressure controlled vapors Crew dons protective masks and suits Neutralizing rinses applied as needed
AIRCRAFT	Not contaminated below safety thresholds, no decontamination required If minimal contamination, automatic release capsules or neutralizers will activate or overpressure for interiors will be active	Interiors protects by controlled vapor overpressure Automatic coatings, release capsules or neutralizers will activate If necessary, rinse with any run-off channeled to phytoremediation area for treatment or captured by advanced absorbent materials for removal
RAILWAY ROLLING STOCKS	Not contaminated below safety thresholds, no decontamination required If minimal contamination, automatic release capsules or neutralizers will activate	Manned interiors protected by controlled vapor overpressure Automatic coatings, release capsules or neutralizers will activate If necessary, rinse with any run-off channeled to phytoremediation area for treatment or captured by advanced absorbent materials for removal
MATERIAL HANDLING EQUIPMENT & SUPPLIES (MOBILE CARGO)	Not contaminated below safety thresholds, no decontamination required If minimal contamination, automatic release capsules or neutralizers will activate	Automatic coatings, release capsules or neutralizers will activate If necessary, rinse with any run-off channeled to phytoremediation area for treatment or captured by advanced absorbent materials for removal
MATERIAL HANDLING EQUIPMENT & SUPPLIES (FIXED CARGO)	Not contaminated below safety thresholds, no decontamination required If minimal contamination, automatic release capsules or neutralizers will activate automatic release capsules or neutralizers will activate	Automatic coatings, release capsules or neutralizers will activate If necessary, rinse with any run-off channeled to phytoremediation area for treatment or captured by advanced absorbent materials for removal
CARGO	Not contaminated below safety thresholds, no decontamination required If minimal contamination, special packaging and coatings will protect or activate neutralizers	Special packaging and coatings will protect or activate neutralizers If necessary, rinse coverings with any run-off channeled to phytoremediation area for treatment or captured by advanced absorbent materials for removal
SENSITIVE/INTERIOR EQUIPMENT		
INTERNAL ATMOSPHERE	Not contaminated below safety thresholds, no decontamination required Building interior and all equipment protected from minimal contamination through interactive filtration and controlled vapor system	Building interior and all equipment protected from minimal contamination through interactive filtration and controlled vapor system or standard filtration Neutralizing coatings activate if needed due to seepage or contamination

TABLE 8.21 WIDE AREA DECONTAMINATION SCENARIOS – EVENT E01		
SCENARIO TARGETS SPECIFIC DECONTAMINATION OBJECTS	SCENARIO E01-A SITE HARDENED AGAINST CHEMICAL THREAT	SCENARIO E01-B SITE SOFT AGAINST CHEMICAL THREAT
OFFICE EQUIPMENT & SUPPLIES	Not contaminated below safety thresholds, no decontamination required	Building interior and all equipment protected from minimal contamination through interactive filtration and controlled vapor system or standard filtration Neutralizing coatings activate if needed due to see page or contamination
MEDICAL EQUIPMENT/SUPPLIES	Not contaminated below safety thresholds, no decontamination required	Building interior and all equipment protected from minimal contamination through interactive filtration and controlled vapor system or standard filtration Neutralizing coatings activate if needed due to seepage or contamination
COMPUTERS	Not contaminated below safety thresholds, no decontamination required	Building interior and all equipment protected from minimal contamination through interactive filtration and controlled vapor system or standard filtration Neutralizing coatings activate if needed due to seepage or contamination
WEAPONS CONTROL SYSTEMS	Not contaminated below safety thresholds, no decontamination required	Building interior and all equipment protected from minimal contamination through interactive filtration and controlled vapor system or standard filtration Neutralizing coatings activate if needed due to seepage or contamination
C&C SYSTEMS	Not contaminated below safety thresholds, no decontamination required	Building interior and all equipment protected from minimal contamination through interactive filtration and controlled vapor system or standard filtration Neutralizing coatings activate if needed due to seepage or contamination
COMMUNICATIONS SYSTEMS	Not contaminated below safety thresholds, no decontamination required	Automatic coatings, release capsules or neutralizers will activate
LARGE AREA		
PORT FACILITIES & DOCKS	Not contaminated below safety thresholds, no decontamination required If minimal contamination, interactive rinsing or chemical neutralizing would occur, such as such as dry ice pellet cleaning or chemical sprays with minimal runoff channeled to bioremediation area	Automatic coatings, release capsules or neutralizers will activate If necessary, rinse with any run-off channeled to phytoremediation area for treatment or captured by advanced absorbent materials for removal
RAIL INFRASTRUCTURES	Not contaminated below safety thresholds, no decontamination required If minimal contamination, interactive rinsing or chemical neutralizing would occur, such as such as dry ice pellet cleaning or chemical sprays with minimal runoff channeled to bioremediation area	Automatic coatings, release capsules or neutralizers will activate If necessary, rinse with any run-off channeled to phytoremediation area for treatment or captured by advanced absorbent materials for removal
ROAD INFRASTRUCTURES	Not contaminated below safety thresholds, no decontamination required If minimal contamination, interactive rinsing or chemical neutralizing would occur, such as such as dry ice pellet cleaning or chemical sprays with minimal runoff channeled to bioremediation area	Automatic coatings, release capsules or neutralizers will activate If necessary, rinse with any run-off channeled to phytoremediation area for treatment or captured by advanced absorbent materials for removal

TABLE 8.21 WIDE AREA DECONTAMINATION SCENARIOS - EVENT E01		
SCENARIO TARGET'S SPECIFIC DECONTAMINATION OBJECTS	**SCENARIO E01.A: SITE HARDENED AGAINST CHEMICAL THREAT**	**SCENARIO E01.B: SITE SOFT AGAINST CHEMICAL THREAT**
OPEN STORAGE YARDS	Not contaminated below safety thresholds, no decontamination required If minimal contamination, interactive rinsing or chemical neutralizing would occur, such as such as dry ice pellet cleaning or chemical sprays with minimal runoff channeled to bioremediation area	Same as above
FIXED COMMUNICATION SYSTEMS	Not contaminated below safety thresholds, no decontamination required If minimal contamination, neutralizing coatings would protect components of the system	Neutralizing coatings activate Apply neutralizing rinses as appropriate
PERSONNEL BARRACKS	Not contaminated below safety thresholds, no decontamination required If minimal contamination, interactive filtration would protect space. Water systems would also be interactively filtered	Overpressure controlled vapors protect interiors Personnel don masks and suits as needed Otherwise, same as above
RECREATION & MESS FACILITIES	Not contaminated below safety thresholds, no decontamination required If minimal contamination, interactive filtration would protect space. Water systems would also be interactively filtered	Irradiation, protective packaging protect consumables Overpressure controlled vapors protect interiors Personnel don masks and suits as needed Otherwise, same as above
WAREHOUSES	Not contaminated below safety thresholds, no decontamination required If minimal contamination, interactive coatings and embedded neutralizers would active or rinsing and chemical neutralizing would occur	Automatic coatings, release capsules or neutralizers will activate If necessary, rinse with any run-off channeled to phytoremediation area for treatment or captured by advanced absorbent materials for removal
REPAIR FACILITIES	Not contaminated below safety thresholds, no decontamination required If minimal contamination, interactive coatings and embedded neutralizers would active or rinsing and chemical neutralizing would occur	Same as above
ADMINISTRATION BUILDINGS	Not contaminated below safety thresholds, no decontamination required If minimal contamination, building interiors and all equipment protected from minimal contamination through interactive filtration and controlled vapor system	Same as above
FIXED WEAPONS SYSTEMS	Not contaminated below safety thresholds, no decontamination required If minimal contamination, command center would be protected by controlled vapor pressure and filtration, equipment would receive interactive rinsing or chemical neutralizing	Same as above
UTILITY INFRASTRUCTURES ON-SITE	Not contaminated below safety thresholds, no decontamination required If minimal contamination, interactive coatings would activate and where appropriate, interactive rinsing or chemical neutralizing would occur	Same as above

TABLE 8.21 WIDE AREA DECONTAMINATION SCENARIOS - EVENT E01		
SCENARIO TARGET'S SPECIFIC DECONTAMINATION OBJECTS	SCENARIO E01.A: SITE HARDENED AGAINST CHEMICAL THREAT	SCENARIO E01.B: SITE SOFT AGAINST CHEMICAL THREAT
UTILITY INFRASTRUCTURES LOCAL	Not contaminated below safety thresholds, no decontamination required If minimal contamination, interactive rinsing or chemical neutralizing would occur, appropriate interactive neutralizing, coatings or rinsing would activate or occur	Same as above
ATMOSPHERE	Decontamination by either laser/light shield or vapor cloud counter release If minimal contamination, proceed to other decontamination strategies after cloud disperses	No action taken, contaminants cleaned after they settle on building, ground, water, and equipment.
SOIL & GROUND	Not contaminated below safety thresholds, no decontamination required If minimal contamination, apply bioremediation directly to areas or apply to runoff	Dig and clean hot spots by using pyrolysis, thermal desorption, or electron beam accelerator, depending on site geology. Use bioremediation directly for remainder of large area, or wash and apply to runoff at bioremediation area.
GROUND WATER	Not contaminated below safety thresholds, no decontamination required If minimal contamination, use bioremediation directly or apply to runoff at bioremediation area	Pump contaminated water through rhyzofiltration system If such a system is not included on-site, pump contaminated water through bioslurry bioreactor
SURFACE WATER	Not contaminated below safety thresholds, no decontamination required If minimal contamination, apply chemical neutralizers or bioremediation remedies	Use permeable reaction wall to contain hot spots, then same techniques as above
MARINE ENVIRONMENT	Not contaminated below safety thresholds, no decontamination required If minimal contamination, apply chemical neutralizers or bioremediation remedies	Apply bio-enzymes to hot spots Use bioremediation, including rhysofiltration to wetlands and shore lines

8.11.3 Event E02: Release of Biological Agents into an Administrative Facility

8.11.3.1 Event. This event is a military or terrorist attack on a major U.S. logistical support facility. The host nation is an important ally who requested U.S. force projection. The facility is located contiguous to the host's largest metropolitan area, the national capital. The specific target is the administration building's internal environment in order to disrupt operations by rendering personnel physically unable to perform their duties by some combination of lethal and/or long-term incapacity.

The threat is a mix of virulent, highly contagious biological agents with the capability to cause debilitating disease and death among operational and deploying personnel. A civilian employee, a host nation national, attaches a canister filled with these biological agents to the administration building's HVAC system and releases the agents. Biological agents quickly spread into the system, posing a serious health risk to personnel. The hazard jeopardizes not only the facility's military mission, but if the infection migrates off site, could disrupt operations at the theater level as well as impacting the host nation's population.

8.11.3.2 Assumptions. Emergency response to this event has the following decontamination objectives:

1) Seal off the personnel and the entire building before the organisms can migrate outside the building
2) Provide "immediate" decontamination of personnel and personal items such as clothing and eye-glasses
3) Provide required medical treatment to immunize personnel within the incubation period or to treat the illness if it is already underway
4) Decontaminate the entire interior space and equipment
5) Ensure that the contaminating organism(s) do not leave the post populations, areas or facilities.

Scenario A: This building has been designated a high priority target and provided maximum proactive and reactive decontamination capabilities. The Integrated System Concepts that have been installed or positioned in proximity to this building are: (note-numbers correspond to Integrated System Concepts)

201: Interactive Filtration: installed in the HVAC system to filter the system at the initial distribution point and the entry/exit ducts for each room.

202: Over Pressured Atmosphere Buildings/Rooms: An over-pressure generator has been installed as a part of the HVAC. It remains passive, however, until given a specific activation command. The key function here is to provide protection from outside infusion - not relevant in this example.

204: Automatic Neutralizing Coatings/Packaging: Sprayed onto all interior equipment whose functions permit this type treatment

302: Controlled Vapors: Buildings Interiors & Rooms: Several of these remote vapor systems have been pre-positioned at high priority locations - one of which is this administrative facility. The system involves a liquefied gas tanker filled with the customized formula. This tanker has several connections for attaching sprayer units - much like multiple fire hoses attach to a fire truck or hydrant(s). Since the facility has been on a "red alert" status, crews are on ready standby. They can be operational around and inside this facility within two to three minutes.

Scenario B: The site has been designated a standard risk area. The proactive measures have not been installed. Reactive systems that have been provided in centralized holding areas of the facility are:

302: Controlled Vapors: Buildings Interiors & Rooms: Same as Scenario A above.
303: Interactive Rinsing: Exterior Surfaces
304: Rinsing with Water/Surfactants

8.11.3.3 Scenarios. The following table includes only the specific targets directly involved in this scenario. Of course additional sites (such as surrounding grounds and nearby assets) must be checked to assure they were not contaminated. Techniques for dealing with them would be essentially the same as was described in the first scenario. This scenario assumes that the core of the telecommunications systems and the weapon system command and control centers are located within the exposed administrative space.

TABLE 8.22 WIDE AREA DECONTAMINATION SCENARIOS - EVENT E02 A		
SCENARIO TARGET'S SPECIFIC DECONTAMINATION OBJECTS	SCENARIO E02 A SITE HARDENED AGAINST CHEMICAL THREAT	SCENARIO E02B SITE SOFT AGAINST CHEMICAL THREAT
SKIN & PERSONAL EQUIPMENT		
OPERATING PERSONNEL	Operating personnel are immediately directed to a specified interior room where a special controlled vapor spray mix is applied. They have carried all personal items with them. Clothing is removed and hung in ways to assure all skin surfaces and personal items are fully "saturated" with the vapor. This immediate decontamination should preclude further medical decontamination or treatment in most cases. However, individuals are examined by medical personnel to ensure decontamination operations were conducted in time to preclude further danger. If this condition is not assured, they are provided on-site immunization or other treatment as needed. In the event the above measures are ineffective on one or more persons, these persons are placed under medical control for the standard treatment that will assure no migration of the organisms into other personnel or operating environments.	Same as Scenario A, except that the delayed warning time may preclude maximum effects of the controlled vapor treatment A significant number of personnel have already ingested the organisms and they are being metabolized into the body systems. These individuals are provided appropriate back up immunization and or treatment as available A significantly larger number of personnel require prolonged medical attention
DRINKING WATER	Water to the building is immediately shut off at the intake valve. The water already in the system is tested. If contaminated, it is drained into treated "water receptacles" for further processing. These receptacles are designed for safe temporary storage and transport. If necessary, these receptacles are transported to a central Bioremediation Center for subsequent decontamination.	Same as Scenario A
PERSONAL TOOLS & WEAPONS	See above cell on Operating Personnel	See above cell on Operating Personnel
CLOTHING	See above cell on Operating Personnel	See above cell on Operating Personnel
SENSITIVE/INTERIOR EQUIPMENT		
INTERNAL ATMOSPHERE	See descriptions for Large Area Components	See descriptions for Large Area Components
OFFICE EQUIPMENT & SUPPLIES	See descriptions for Large Area Components All equipment has been pre-coated (internal and external) with interactive coating systems	See descriptions for Large Area Components No pre-coating of equipment, thus requiring increased vapor applications ... lost time may have increased the contamination and hence exposure of operating personnel
MEDICAL EQUIPMENT/SUPPLIES	See descriptions for Large Area Components All equipment has been pre-coated (internal and external) with interactive coating systems	See descriptions for Large Area Components No pre-coating of equipment, thus requiring increased vapor applications ... lost time may have increased the contamination and hence exposure of operating personnel
COMPUTERS	See descriptions for Large Area Components All equipment has been pre-coated (internal and external) with interactive coating systems	See descriptions for Large Area Components No pre-coating of equipment, thus requiring increased vapor applications ... lost time may have increased the contamination and hence exposure of operating personnel

TABLE 8.22 WIDE AREA DECONTAMINATION SCENARIOS - EVENT E02.A		
SCENARIO TARGETS: SPECIFIC DECONTAMINATION OBJECTS	SCENARIO E02.A: SITE HARDENED AGAINST CHEMICAL THREAT	SCENARIO E02.B: SITE SOFT AGAINST CHEMICAL THREAT
WEAPONS CONTROL SYSTEMS	See descriptions for Large Area Components All equipment has been pre-coated (internal and external) with interactive coating systems	See descriptions for Large Area Components No pre-coating of equipment, thus requiring increased vapor applications ... lost time may have increased the contamination and hence exposure of operating personnel
C & C SYSTEMS	See descriptions for Large Area components All equipment has been pre-coated (internal and external) with interactive coating systems	See descriptions for Large Area Components No pre-coating of equipment, thus requiring increased vapor applications ... lost time may have increased the contamination and hence exposure of operating personnel
COMMUNICATION SYSTEMS	See descriptions for Large Area components All equipment has been pre-coated (internal and external) with interactive coating systems	See descriptions for Large Area Components No pre-coating of equipment, thus requiring increased vapor applications ... lost time may have increased the contamination and hence exposure of operating personnel
LARGE AREA		
FIXED COMMUNICATION SYSTEMS	The communication facilities have been pre-coated with embedded interactive coatings which act as a double safety backup which protects the communication components internally and externally "clean" The controlled vapor system takes care of the surrounding spaces. This room is returned to operational status within less than 1 hour.	No pre-coating of equipment, thus requiring increased vapor applications ... lost time may have increased the contamination and hence exposure of operating personnel
ADMINISTRATION BUILDINGS	Preinstalled interactive filters in the HVAC system have either eliminated the effective contamination or significantly reduced it. These filters have neutralizing and absorbent capabilities that continue to perform their function as the air continues to circulate; hence the HVAC system should remain operating. The controlled vapor spray system is instantly activated as soon as the HVAC filter has signaled presence of a dangerous organism. Retrained and suited crews start simultaneous diffusion of controlled vapors in all interior spaces and around the exterior of the building. This exterior application essentially "seals off" the building and decontaminates any migrating organisms. The interior infusions act to decontaminate all interior surfaces, including the cracks and crevices, and all interior equipment. Within less than five minutes the backup controlled vapor system is fully diffused. The final monitoring team now arrives with specialized sensors to determine what if any residual actions are needed. The entire building is returned to operational status within 2 hours or less.	There are no interactive filters ... sensors do not activate until the internal space reaches the threshold contamination levels ... all delivered organisms are dispensed into the internal atmospheres of all rooms connected to the HVAC system. This delay significantly increases the level of decontamination and the time required to restore operational safety Same as Scenario A: except that the time delay associated with delayed sensing creates greater decontamination levels ... the probability that migration into outside environments is increased ... likely need for standard rinsing and treatment of residuals is increased, along the extended time to restore full operational safety.

8.11.4 Event E03: Personnel Exposure To Biological Agents In Showers

8.11.4.1 Event. This event is a military or terrorist attack on a major U.S. logistical support facility. The host nation is an important ally who requested U.S. force projection. The facility is located contiguous to the host's largest metropolitan area, the national capital. The specific target is the internal environment of a very large barracks. The goal is to disrupt operations by rendering personnel physically unable to perform their duties by some combination of lethal and/or long-term incapacity.

The threat is a mix of virulent, highly contagious biological agents with the capability to cause debilitating disease and death among operational and deploying personnel. A civilian employee, a host nation national, places a water dispersible package containing these biological agents into the building's hot water heater. As the package dissolves, biological agents quickly spread into the system. Personnel are exposed to the pathogens as they shower or use the hot water facet, posing a serious health risk. The hazard jeopardizes not only the facility's military mission, but if the infection migrates off site, could disrupt operations at the theater level as well as impacting the host nation's population.

8.11.4.2 Assumptions. Emergency response to this event has the following decontamination objectives:

1) Isolate exposed personnel and seal the entire building before the organisms can spread to other areas and infect other personnel
2) Ensure fast decontamination of personnel and personal items
3) Provide required medical treatment to immunize personnel within the incubation period or to treat the illness if it has a short incubation.
4) Decontaminate the entire interior space and equipment
5) Ensure that the contaminating organism(s) do not migrate off site

Scenario A: As was the case for the Administrative building that was targeted in Scenario E02, the barracks is considered to be a high priority target. Planners provided maximum proactive and reactive decontamination capabilities. Interior walls are advanced composites with embedded biological and fiber optical sensors. The Integrated System Concepts that have been installed or positioned in proximity to this building are:

201: Interactive Filtration: installed in the system to filter the water at the building's main utility connection point. Each shower head and faucet are also filtered.

202: Over Pressured Atmosphere Buildings/ Rooms: An over-pressure generator has been installed as a part of the HVAC system. It remains passive, however, until given a specific activation command. The key function here is to provide protection from outside infusion - not relevant in this example.

204: Automatic Neutralizing Coatings/Packaging: Sprayed onto all interior equipment whose functions permit this type treatment

302: Controlled Vapors: Buildings Interiors & Rooms: Several of these remote vapor systems have been pre-positioned at high priority locations - one of which is the barracks. The system involves a liquefied gas tanker filled with the customized formula. This tanker has several connections for attaching sprayer units - much like multiple fire hoses attach to a fire truck or hydrant(s). Since the facility has been on a "red alert" status, crews are on ready standby. They can be operational around and inside this facility within two to three minutes.

Scenario B: The site has been designated a standard risk area. The proactive measures have not been installed. Reactive systems that have been provided in centralized holding areas of the facility are:

302: Controlled Vapors: Buildings Interiors & Rooms: Same as Scenario A above.
303: Interactive Rinsing: Exterior Surfaces
304: Rinsing with Water/Surfactants

8.11.4.3 Scenarios. The scenario table includes only the specific targets directly involved in this event. Additional areas (such as surrounding grounds and nearby assets) must be monitored to assure that they were not contaminated. Techniques for dealing with such areas would be essentially the same as was described in the first scenario.

TABLE 8.25
WIDE AREA DECONTAMINATION SCENARIOS – EVENT E03

SCENARIO TARGETS SPECIFIC DECONTAMINATION OBJECTS	SCENARIO E03 A SITE HARDENED AGAINST BIOLOGICAL THREAT	SCENARIO E03 B SITE SOFT AGAINST BIOLOGICAL THREAT
SKIN & PERSONAL EQUIPMENT		
OPERATING PERSONNEL	The filters within each shower kill the pathogens before personnel are infected. Wall sensors alert staff that a biological agent has been located. The water system is shut down, and bioremediation agents are released into the site's water utility to ensure that the biological agent does not migrate. As a precaution, operating personnel are immediately directed to a specified interior room where a special controlled vapor spray mix is applied. They have carried all personal items with them. Clothing is removed and hung in ways to assure all skin surfaces and personal items are fully "saturated" with the vapor. The decontamination should preclude further medical treatment in most cases. However, the personnel are examined by medical personnel and equipment to assure they are healthy and are isolated through the pathogen's incubation period	Operating personnel are exposed to the biological agents as they use hot water. The contamination is discovered during routine monitoring. Scenario A vapor treatment is used. The delayed warning time may preclude maximum effects of the controlled vapor treatment A significant number of personnel have already been exposed to the biological agents. These individuals are isolated and are provided appropriate immunization and medical treatment A large number of personnel require medical attention and the entire site must be isolated during the pathogen's incubation period. This means that supplies cannot be moved forward, functionally closing the facility.
DEPLOYING FORCE PERSONNEL	Same as above	Same as above Deploying force personnel must remain on-site during the pathogen's incubation period, delaying troop movement significantly
DRINKING WATER	The water system is shut down. Bioremediation agents are released into the site's water utility to ensure that the biological agent does not migrate and is contained and destroyed.	Water to the building is immediately shut off at the intake valve. The water already in the system is drained into treated "water receptacles" for further processing. These receptacles are designed for safe temporary storage and transport. If necessary, these receptacles are transported to a central Bioremediation Center for subsequent decontamination The facility's water utility is shut down, and bioremediation agents are released to ensure that the biological agent does not migrate and is contained and destroyed
FOOD, MEDICINE & OTHER CONSUMABLES	See cell on Operating Personnel	See cell on Operating Personnel
PERSONAL TOOLS & WEAPONS	See cell on Operating Personnel	See cell on Operating Personnel
CLOTHING	See cell on Operating Personnel	See cell on Operating Personnel

SENSITIVE/INTERIOR EQUIPMENT		
INTERNAL ATMOSPHERE	See cell on Operating Personnel	See cell on Operating Personnel
OFFICE EQUIPMENT & SUPPLIES	All equipment has been internally and externally coated with interactive coating systems	No pre-coating of equipment, thus requiring increased vapor applications and disinfectant washing ... lost time may have increased the contamination and hence exposure of operating personnel
MEDICAL EQUIPMENT/SUPPLIES	All equipment has been internally and externally coated with interactive coating systems	No pre-coating of equipment, thus requiring increased vapor applications and disinfectant washing ... lost time may have increased the contamination and hence exposure of operating personnel
COMPUTERS	All equipment has been internally and externally coated with interactive coating systems	No pre-coating of equipment, thus requiring increased vapor applications and disinfectant washing ... lost time may have increased the contamination and hence exposure of operating personnel
COMMUNICATION SYSTEMS	All equipment has been internally and externally coated with interactive coating systems	No pre-coating of equipment, thus requiring increased vapor applications and disinfectant washing ... lost time may have increased the contamination and hence exposure of operating personnel
LARGE AREA		
PERSONNEL BARRACKS	Preinstalled interactive filters in the water system have either eliminated the effective contamination or significantly reduced it. These filters have neutralizing and absorbent capabilities that continue to perform their function as the water continues to circulate; hence the water system should remain operating. The controlled vapor spray system is instantly activated as soon as the filter has signaled presence of a dangerous organism. Retrained and suited crews start simultaneous diffusion of controlled vapors in all interior spaces and around the exterior of the buildings. This exterior application essentially "seals off" the building and decontaminates any migrating organisms. The interior infusions act to decontaminate all interior surfaces, including the cracks and crevices, and all interior equipment. Within less than five minutes the backup controlled vapor system is fully diffused. The final monitoring team now arrives with specialized sensors to determine what if any residual actions are needed. The entire building is returned to operational status within 2 hours or less.	There are no interactive filters ... sensors do not activate until the internal space reaches the threshold contamination levels ... all delivered organisms are dispensed into the internal atmospheres of all rooms as infected personnel contact uninfected personnel. Personnel outside the barracks are infected through the same contact, until the barracks is isolated. This delay significantly increases the level of decontamination and the time required to restore operational safety Same as Scenario A: except that the time delay associated with delayed sensing creates greater decontamination levels ... the probability that migration into outside environments is increased ... likely need for standard rinsing and treatment of residuals is increased, along the extended time to restore full operational safety.

9.0 Summary Assessment

At the conclusion of the three efforts performed (Literature Search, Market Survey, and the Out-of-the-Box Study), a detailed assessment of the results was performed. The objective of the summary assessment was to assess the technologies and equipment identified to determine those that offered the most promise for meeting the immediate needs of the Wide Area Decontamination Program. The summary assessment also includes a detailed examination of the potential use of combining the technologies and equipment identified into hardware solutions for immediate implementation.

The approach taken for the summary assessment involved a determination of technologies and equipment that were deemed ready for use or testing. In order to make this determination, a three-year timeframe was chosen. The reason this period was selected was to identify military or commercial equipment that had been developed and tested against CB agents, or equipment that was ready but needed agent testing. Thus, some of the commercial equipment that appears on the list could be used for decontamination purposes but requires some confirmatory agent testing first. For example, the Snow Motion and Cryogenesis Ice Gun items of equipment may be used for sensitive equipment decontamination.

Decontamination of equipment and personnel can be generalized into four different physical properties or categories. Approaches for decontamination of equipment involve, either individually or in combination, the application of chemical, thermal or mechanical processes. Obviously, chemical processes address the physical destruction or transformation of the CB agent. Within this category, there are many subcategories that reflect the chemical nature of the agents. Due to their varied chemical properties such as viscosity, miscibility, vapor pressure, composition, and so on, different chemical techniques and approaches must be used. A chemical system, such as DS2 that is effective against all agents, may also damage the piece of equipment that it is decontaminating. Thus, various subcategories of chemical processes must be used to destroy the CB agents.

Employing thermal or mechanical processes in concert with chemical processes can also enhance the effectiveness of the decontamination process. Thermal or mechanical processes alone rarely destroy the agents, with the exception of pyrolysis or incineration, but serve to remove agent contamination from surfaces. The major challenge for equipment decontamination, without rendering the item of equipment useless, lies in removing residual agent from cracks, crevices and other inaccessible spots such as screw wells.

For personnel decontamination, the approach usually involves sorbents and/or reactive creams and solutions. For the most part, sorbents involve the physical removal of the chemical agent from the skin. Research is ongoing to develop reactive or catalytic sorbents that can destroy the agents. Reactive creams and solutions act to neutralize the residual agent left on the skin.

During the conduct of this study, it became apparent that the generic term "fixed site" could be applied equally to those activities and equipment that pertain to air bases, sea ports, and logistic and communication centers. Analysis of the various technologies and equipment indicated that they could be applied to all sites and not just one or the other; thus, these sites are described under the generic term. However, there were some circumstances where a technology or item of equipment was particularly appropriate. These situations involved decontamination of large structures and buildings, tracts of terrain, and transportation infrastructure. Therefore, another category, Large Area, was created to address this situation.

9.1 Technologies

Using the approach identified above, the technologies identified during the course of this effort were assessed for their near-term availability. Many technologies are mature (M), much is known about them, and they are in use today. In some cases, novel or evolutionary adaptations are being made to enhance their capabilities. Other technologies, in contrast, are not at the same level of maturity since they may be emerging (E) technologies or they may be in the process of being adapted from another use. A good example of this is low temperature plasma technology that is used extensively in the automotive industry.

Decontamination categories were assigned to each technology based on applicability. Table 9.1 summarizes the relationships between the identified technologies and categories. An assessment of the relative maturity is also included.

Table 9.1. Technology Summary

Technology	Skin	Personal Equipment	Exterior Equipment	Interior Equipment	Sensitive Equipment	Large Area
Coatings/Paints			M	M		M
Electrochemical	E	E	E			E
High Pressure						
- $SCCO_2$		E			E	
- SCWO			Effluents			Effluents
Low Temperature		M	M	M	M	
Reactive Chemistry	M	M	M	M		M
Sorbents	M	M				
Mechanical						
- CO2		E	E	E		E
- Water		M	M			M
- Ultrasonic		E	E			E
- RO			Effluents			Effluents
Weathering		M	M	M	M	M
Directed Energy						
- Cold Plasma		E			E	
- Hot Plasma			E			
- Corona Disc			Effluents			Effluents
- Gamma Irrad		E				
Bio Processes						
- Enzymes	E	E	E	E		E
- Phytoremediation						E

M – *Mature Technology*
E – *Emerging Technology*

9.1.1 Coatings and Paints

Coatings and Paints is a mature technology. The primary application involves CARCs that are widely used on equipment. The purpose of the CARC is mainly protective; however, research is on going to extend this technology and identify novel approaches and techniques to make the coatings reactive or catalytic toward agent.

9.1.2 Electrochemical

This is an emerging technology with respect to decontamination. While it is a mature technology, its application to this area is relatively new. The most interesting application involves passing a current through a brine solution to produce an Electrochemical Activated solution (ECASOL). Preliminary testing indicates that it is highly effective against anthrax and botulinum toxin A as well as GD and HD, to some extent. This technology application warrants further testing.

9.1.3 High Pressure (Supercritical Fluids)

$SCCO_2$ extraction is another emerging technology with respect to decontamination. This technology has extensive application in the food industry. This technology has application to sensitive equipment and personal equipment small enough to fit into the chamber. Based on its characteristics, this technology may be able to penetrate cracks and crevices and remove agent located there. A program is currently underway to determine its viability for chemical agent decontamination.

Commercial application of SCWO is just starting to emerge. Application of this technology appears to be directed as a polishing or post-treatment step to destroy organic material up to about a 10% concentration. Thus, the best use for this technology may involve decontamination operations where large volumes of effluent are generated and collected. There are several items of equipment from the hazardous material field that use retaining basins to capture effluents. Small, portable SCWO units could be utilized to treat the collected effluent from the retaining basins. This technology warrants further consideration.

9.1.4 Low Temperature Thermal (Accelerated Weathering)

This is another mature technology with a large number of equipment developed based on this approach. In addition, extensive testing has been done involving various operational scenarios. The amount of time required to use this technology is the main consideration, though. Depending on the degree of contamination, an extended period of time may be required to drive agent concentrations to a safe level. For small items of equipment and low agent contamination, a heated chamber with associated carbon filter can be used effectively. For larger items of equipment, a portable heater commonly used at construction sites during winter is effective, as well. However, consideration must be given to the downwind hazard that is created.

9.1.5 Reactive Chemistry

This area has been extensively researched and evaluated. Numerous decontamination equipment and applications are based on the chemical reaction and destruction of CB agents. In most cases, the chemical decontaminants developed for chemical agents are equally effective against biological agents. Due to the physical properties of the agents, it is rare to have one chemical decontaminant equally effective against all of the agents. DS2 is effective against all agents however, it is so aggressive that it damages the equipment it is decontaminating. There are two basic chemical approaches for chemical decon: oxidation and nucleophilic substitution (hydrolysis). Oxidation is effective against V-, H-agents and most biological agents while nucleophilic substitution is effective against G-agents and, to some extent, HD. Due to the relative inability of V- and H-agents to mix with water, additives, such as surfactants and organic solvents, are used to get them into solution where they can react. The difficult challenge in this area is to identify a decontaminant that is effective against all agents, is environmentally friendly, and is non-corrosive.

9.1.6 Sorbents

This technology has extensive application in the commercial sector as well as in military equipment developed for skin and personal equipment decontamination. A program is nearing completion that will replace the sorbent, XE-555, contained in the M291 skin decontamination kit with a choice of two comparable sorbent materials with reactive and catalytic properties. However, use of the upgraded kit will be limited to personal equipment decontamination until it has been approved for human use. In addition, this material will be used to replace DS2 in the M11/M13 decontaminating apparatus for application to small equipment or in areas where the soldier operates. This is a mature technology that can be readily adapted to different uses and applications.

9.1.7 Mechanical

Pressurized water is a mature technology with extensive application in commercial industry. This technology is used to clean equipment and machinery, buildings, structures and surfaces such as roadways. To enhance the effectiveness of the process, the water can be heated and detergents can be added. It is also extensively used in military applications for similar purposes. In addition, it is used to physically remove CB agent contamination from surfaces. However, since it is generally a non-reactive process, a hazard exists with the resulting liquid run-off. A secondary post-treatment technology is required to treat it to remove the hazard.

In a recent development, pressurized carbon dioxide is starting to be applied to the same type of situations that pressurized water systems would be used. It has the added benefit in that it produces a much-reduced waste stream that only involves the contaminant. The carrier, carbon dioxide, simply vaporizes and leaves only the contaminant behind. This is in contrast to a water system that produces large quantities of waste. Safety measures for pressurized carbon dioxide cleaning are required since the agent contamination is not contained and could produce a downwind hazard.

Ultrasonic technology also has widespread use in cleaning small items. It uses a cleaning solution in conjunction with ultrasonic waves generated by a transducer to create an intense scrubbing action. This scrubbing action effectively removes dirt and oil from small instruments and electronic and optical components with the appropriate solution. This technology could be used to decontaminate sensitive equipment.

Reverse osmosis is commonly used to purify water for drinking purposes as well as providing ultrapure water for laboratory use. For decontamination purposes, however, it serves as a polishing technology or effluent treatment process to remove trace organic compounds or chemical agents from water.

9.1.8 Weathering

Weathering is usually a natural process that involves solar radiant energy, wind or rain to remove agent contamination from a surface. Evaporation of the agent usually occurs. However, weathering is a time-dependent process that is determined by the amount of agent on the item of equipment. For large concentrations of agent, it may be impracticable to allow weathering to occur due to the length of time required. It could be used in conjunction with another technology to remove gross agent contamination and significantly reduce the personnel hazard.

9.1.9 Directed Energy

Oxygen plasmas can be employed in two different techniques and both are used commercially in the automotive industry. Cold or low-pressure oxygen plasmas require a chamber in order to operate which limits the size of the item that can be treated. Due to the invasive nature of the plasma, this process should be able to remove contamination contained in cracks and crevices. However, items sensitive to pressure could be damage. Hot or atmospheric pressure oxygen plasmas are limited in their applications. They are used to polish surfaces such as automobile bumpers.

Corona discharge plasmas are primarily used as an effluent treatment technology to remove trace organic compounds from a gas stream. In addition, corona discharge plasmas produce ozone as a by-product and appropriate safety and health measures would have to be taken. Thus, this technology would not be appropriate to decontaminate an item of equipment.

Gamma irradiation is used extensively in the commercial sector to clean medical instruments as well as kill bacteria, insects or parasites that may reside on or within food. It ionizes compounds and produces intermediate compounds, which effectively sanitize and sterilize the target item. Its application to destruction of chemical compounds, much less than chemical agents, is uncertain and testing would be required. Due to radiation shielding, personal protection and power required, this technology might not be suitable for decontamination operations.

9.1.10 Biological Processes

Enzymes are used extensively in household cleaning as well as industrial applications. Enzymes have been found which effectively decontaminate G-agents but limited success has been achieved to find enzymes to decontaminate V- and H-agents. This field shows promise in greatly reducing the logistical burden associated with decontamination activities through a reduced utilization of water.

Bioremediation or biodegradation is used extensively in the environmental field for clean up of soil contaminated with organic or trace metal compounds. Many technologies are used to treat the affected area, and due to the heterogeneous nature of the soil and the physical properties of the contaminant, various levels of clean up are achieved in this time consuming process. This technology would be applicable to treat terrain contaminated with agent. However, extensive testing would be required to determine the environmental fate of the chemical agents and the applicability of the many bioremedial techniques.

The use of fungi to decontaminate chemical agents is just being studied and is immature at this point. Additional research would be required to bring it to the point where it could be applied to a decontamination situation.

9.2 Equipment

Several items of equipment were identified that were applicable for decontamination operations or had the potential to be applied. The equipment was divided into two categories: military and commercial equipment. The military equipment category could be further divided into U.S. and international military equipment. The U.S equipment was not identified in Table 9.2 since the intended audience of this report is assumed to be familiar with them. They are, however, described in Section 6.0 of this report. In both cases, there are great similarities between them. For example, pressure washers and hot air equipment have been developed and are used by many countries.

Table 9.3 has been developed to identify commercial equipment that has the potential to be applied to decontamination situations. Obviously, these equipment items would have to be tested to determine their effectiveness in removing or destroying CB agent. However, they are commercially available and can be readily procured.

Table 9.2. Foreign Military Decontamination Equipment

CHEMICAL	THERMAL	MECHANICAL	SORBENT
Skin and Personal Equipment	*Skin and Personal Equipment*	*Skin and Personal Equipment*	*Skin and Personal Equipment*
Decocontain 3000	Karcher DT 60	Decocontain 3000	Glove mle F1
Karcher Decon Trailer	Hot Air Unit VA-8	Karcher DS 10	KID-6 and KID12
Karcher DS 10	*Exterior Equipment*	Karcher SCS 1800 DE	Decon Kit No.2
Skin Decontaminant Lotion (SDL)	ADTT-1	ST-T815	
ST-T815	Protector-N	NBC-DEWDON-PERS	
NBC-DEWDON-PERS	*Sensitive Equipment*	OWR DEDAS	
OWR DEDAS	Karcher AEDA1	M-82	
Models DDA-53 Series	*Large Area*	Models DDA-53 Series	
FMG-90	Protector-N	FMG-90	
Reactive SDL		*Exterior Equipment*	
Exterior Equipment		UMTH 1000	
Decocontain 3000		Decocontain 3000	
Karcher Decon Trailer		Karcher C8-DADS	
Karcher C8-DADS		Karcher DS 10	
Karcher DS 10		Karcher SCS 1800 DE	
ST-T815		ST-T815	
SANIJET Gun		SANIJET C921	
NBC-DEWDON-20L		SANIJET Gun	
ARS-14K		ARS-14K	
NBC Decon Truck		NBC Decon Truck	
OWR DEDAS		OWR DEDAS	
DAP 2		Model IRS	
Protector-N		Model TZ-74	
Model IRS		FMG-90	
Model ADK		*Sensitive Equipment*	
Model TZ-74		Karcher AEDA1	
FMG-90		*Large Area*	
Large Area		Decocontain 3000	

CHEMICAL	THERMAL	MECHANICAL	SORBENT
Skin and Personal Equipment	*Skin and Personal Equipment*	*Skin and Personal Equipment*	*Skin and Personal Equipment*
Decocontain 3000		Karcher C8-DADS	
Karcher C8-DADS		ST-T815	
ST-T815		ARS-14K	
ARS-14K		NBC Decon Truck	
NBC Decon Truck		Model IRS	
M-73-1		FMG-90	
Protector-N			
Model IRS			
FMG-90			

Table 9.3. Commercial Equipment with Potential Decontamination Use

CHEMICAL	MECHANICAL	SORBENT	DIRECTED ENERGY	MISC
Skin/Personal Equipment	*Skin/Personal Equipment*	*Skin/Personal Equipment*	*Skin/Personal Equipment*	Speedi-Berm
Mobile Decon Pad	Decon Glove Booths	Commercial Absorbents	PLASCON	Port-A-Berm
Exterior Equipment	Mobile Decon Pad			
Mobile Decon Pad	Hughes Safety Showers			
High-Volume Sprayer	DeCon Hoop			
Large Area	*Exterior Equipment*			
High-Volume Sprayer	Decon Glove Booths			
	Mobile Decon Pad			
	High-Volume Sprayer			
	APZ			
	Sensitive Equipment			
	Snow Motion			
	Optimum Console			
	Cryogenesis Ice Gun and Booth			
	Vapormaster 1325			
	SS-GLCS			
	Delta V-1			
	Large Area			
	Corner-Cutter			
	Moose			
	Roto-Peen Scaler			
	Squirrel-III			
	High-Volume Sprayer			
	APZ			

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APPENDIX A: List of Keywords

General Keywords
Sealant$
Biological and Agent$ and decon$
Chemical and Agent$ and decon$
Decontamination Apparatus
Decontamination Device$
Decontamination Equipment
Decontamination Kit$
Decontamination Method$
Decontamination Procedure$
Decontamination Process$
Decontamination Regulation
Decontamination Requirement$
Decontamination Standard
Decontamination Technology$
Field Expedient Decontamination
Microb$ and decon$
Pathogen$ and decon$
Toxin$ and decon$
Skin & Personnel Equipment Decontamination
Body Decontamination
Crew Decontamination
Personal Decontamination
Personnel Decontamination
Personnel Equipment Decontamination
Skin Decontamination
Soldier Decontamination
War Fighter Decontamination
Equipment & Exterior Decontamination
Aircraft Decontamination
Electric Discharge Reactor
Equipment Decontamination
Exterior Decontamination
Flashlamp
Hot Air Decontamination Equipment
Large Equipment Cleaning and NBC Decon Facility
Laundry and Decontamination Dry Cleaning System
M11 Portable Decontamination Apparatus
M12A1 Decontaminating Apparatus
M13 Individual Decontamination and Reimpregnating Kit
M13 Portable Decontamination Apparatus
M15 Interior Surface Decontamination System
M16 Jet-Exhaust Decontamination System
M17 Lightweight Decontamination System
M17E1 NBC Sanator
M19
M258 Skin Decontaminating Kit
M258A1 Personal Decontamination Kit
M258A2 Personal Decontamination Kit

M280 Decontamination Kit
M291 Skin Decontamination Kit
M295 Individual Decontamination Kit
M58A1 Training Aid Kit
MDS
MEDICLEAN 2000
NAEDS
Personal Equipment Cleaning and Decontamination System
RMS-65
Ship Decontamination
SM56 Smoke/Decontamination System
Spray Equipment
Surface$ Decontamination
TMS-65
Vehicle$ Decontamination
Water Jet$
Weapon$ Decontamination
XM11 Portable Decontamination Apparatus
XM12A1 Decontaminating Apparatus
XM13 Individual Decontamination and Reimpregnating Kit
XM13 Portable Decontamination Apparatus
XM15 Interior Surface Decontamination System
XM16 Jet-Exhaust Decontamination System
XM17 Lightweight Decontamination System
XM17E1 NBC Sanator
XM19
XM258 Skin Decontaminating Kit
XM258A1 Personal Decontamination Kit
XM258A2 Personal Decontamination Kit
XM280 Decontamination Kit
XM291 Skin Decontamination Kit
XM295 Individual Decontamination Kit
XM58A1 Training Aid Kit
Sensitive & Interior Equipment Decontamination
Display$ Decontamination
Electronic$ Decontamination
Instrument$ Decontamination
Interior Equipment Decontamination
Interior Surface$ Decontamination
Sensitive Equipment Decontamination
Fixed Site Decontamination
Airstrip Decontamination
Building$ Decontamination
Facility Decontamination
Fixed-Site Decontamination
Fixed Site Decontamination
Laborator$ Decontamination
Port of Embarkation Decontamination
Port of Entry Decontamination
Runway Decontamination
Soil Decontamination
Terrain Decontamination

Wall Decontamination
Wide Area Decontamination
Decontaminants
Antimicrobial
Bactericid$
Biocide$
Decontaminant$
Decontaminating Agent$
Decontamination Agent$
Disinfectant$
Specific Decontaminants
Activated Solution of Hypochlorite
AFFF - Aqueous-Film Forming Foam
Air Force Steam Cleaning Solution
Alcide
Alumina
Aminomethane
Ammonia
Ammonium Hydroxide
APD - All-Purpose Decontaminant
ASH – Activated Solution of Hypochlorite
ASHN - Navy ASH
BETAP – Beta-Propiolactone
Bleach
Bleaching Powder
Bromodimethyloxazolidinone
C-8 Emulsion
Calcium
Calcium Hypochlorite
Calcium Oxide
Calcium Oxychlorite
Carboxide
Catechol
Caustic Potash
Caustic Soda
CD1 – Chemical Decontaminant No. 1
CD1-V – Chemical Decontaminant No. 1 – Variant
CDS – Calcium Dodecylbenzene Sulfonate
CFC-113 – Trichlorotrifluoroethane
Chloramine B – Sodium Benzenefulfochloramide
Chloramine T – Sodium Para-toluenesulfochloramine
Chloride of Lime
Chlorinated Lime
Chlorine
Chlorine Dioxide
Chlorodimethyloxazolidinone
Citric Acid (Anhydrous)
Citric Acid Monohydrate
Clay$
Clinoptilolite
Cobalt Tetrasulfophthalocyanine
CTAB - Cetyltrimethylammonium Bromide
CTAC – Cetyltrimethylammonium Chloride

DANC – Decontamination Agent - Noncorrosive
Detergent$
DETR – Detrochlorite
Dibromodimethylhydantoin
DICB – Dichloramine B
DICT – Dichloramine T
Diethylamine
Diethylenetriamine
Dimethyl Sulfoxide
Dimethylaminopyridine
Docosyl Groups
DS2, DS-2, Decontaminating Solution No. 2
EGME – Ethylene Glycol Monomethyl Ether
Emulsifier$
Emulsion$
Ethanol – Ethyl Alcohol
Ethanolamine
Ethylene Glycol – Ethylene Alcohol
Ethylene Glycol Monobutyl Ether
Ethylene Glycol Monoethyl Ether
Ethylene Oxide
Ethylenediamine
Formalin
Freon$ - Chlorotrifluoromethane, dichlorodifluoromethane, trichlorofluoromethane
Fuel$
Fuller's Earth
German Emulsion
Glycerol
Glyoxalin
H48, H-48
Hot Air
Hot Gas$
HTH - High Test Hypochlorite
Hyamines
Hydrogen Peroxide
Hydrogen Sulfate
Hydroxamic Acid
Hydroxide Reactants
IBA - Iodosobenzoic Acid
ICBAD – Improved Chemical-Biological Agent Decontaminant
Imidaxole
IPA – Isopropanol
Lactic Acid
Lithium Hypochlorite
Magnesium Hydroxide
Magnesium Monoperoxyphthalate
MCBD – Multipurpose Chemical-Biological Decontaminant
Methyl Amine
Methyl Chloroform
Microemulsion$
Microorganism$
MIL-C-25769 Formula
Monoclonal Antibod$

Navy SLASH – Navy Self-Limiting ASH
Nitric Acid
Nitrobenzylpyridine
Oxychlorite
PAA, Peroxyacetic Acid, Peracetic Acid
PEG – Polyethylene Glycol, Polyether Glycol, Polyglycol, Polyoxyethylene
PEG 200 – Polyethylene Glycol 200
Perchloroethylene
Perchloryl Fluoride
Phenol
Phosphonic Acid
Polyethylenimine
POTA – Polyoxyethylene Tetradecyl Alcohol
Potassium Hydroxide
Protein Binder$
Pyridinium Aldoxime
Reactive Polymer$
Reactive Resin$
Saline Solution
Sea Water
SLASH
SOCA - Sodium Carbonate
Sodium Acetate
Sodium Chlorite
Sodium Dichloroisocyanurate
Sodium Hydroxide
Sodium Hypochlorite
Sodium Perborate
Sodium Persulfate – Sodium Peroxydisulfate
Sodium Tripolyphosphate, Sodium Triphosphate, STPP
Soil Microorganism$
Solvent$
Sorbent$
STB – Supertropical Bleach
Steam
Stoddards Solvent
Sulfuric Acid
Supercritical Carbon Dioxide
Supercritical Fluid$
Surfactant$
Trichloroethylene
Triethylenediamine
Water
Wetting Agent$
Zeolites
Decontamination
Cleanup and decon$
Contamination Control and decon$
Deactivation and decon$
Decomposition
Denaturation
Detoxification
Disinfect$
Kill
Neutralize$
Sterilize$

Specific Decontamination Processes
Absorption
Adsorption
Aeration
Boiling
Catalysis
Chemical Reaction$
Chlorination
Cryogenics
Dilution
Electrical Discharge
Electrical Heating
Encapsulation
Flaming
Flashblasting
Gamma Radiation Processing
Hydrolysis
Incineration
Laser Decontamination
Laundering
Liquid Extraction
Microencapsulation
Microwave
Neutralization
Osmosis
Oxidation
Photochemical Decontamination
Photo-chemical Techniques
Photolysis
Photooxidation
Physical Removal of Agents
Plasma Discharge
Pyrolysis
Radiant Heating
Reduction
Sandblasting
Sorbent Particles
Sorption
Spalling
Thermal Decomposition
Ultrasonic Decomposition
Ultraviolet Irradiation
Weathering
Proactive Decontamination
CARC
Chemical Agent Resistant Coating$
Contamination Avoidance Cover$
Reactive Coating$
Sacrificial Coating$
Self-decontaminating Coating$
Thin Film Conductive Coating$

APPENDIX B: Database Fields Associated with the Four Government Databases

CBDCOM	CBIAC	DTIC	DUGWAY
ACCESSION NUMBER	CBIAC NUMBER	AD NUMBER	ACCN
TITLE	AD NUMBER	TITLE	AD
DISPTITLE	DOCUMENT CONTROL NUMBER	DISPTITLE	TI
LOCATION	TITLE	ITEM LOCATION	DISPTITLE
AUTHOR(S)	DISPTITLE	PERSONAL AUTHORS	COLL
REPORT DATE	SITE HOLDING	REPORT DATE	AUTH
DESCRIPTIVE NOTE	SECURITY FIELD	DESCRIPTIVE NOTE	DATE
DIST/AVAIL STMT	AUTHOR(S)	LIMITATIONS (ALPHA)	NOTE
REPORT NUMBER(S)	PUBLICATION DATE	REPORT NUMBER	DIST
REPORT CLASS	DESCRIPTIVE NOTE	REPORT CLASSIFICATION	RPT
CONTRACT NUMBER(S)	LIMITATIONS/ AVAILABILITY	CONTRACT NUMBER	RPCL
PAGINATION	REPORT NUMBERS	REPORT CLASSIFICATION	CONT
CORPORATE AUTHOR	DOCUMENT CLASSIFICATION	CONTRACT NUMBER	PAGE
SUPPLEMENTARY NOTE	CONTRACT NUMBER	PAGINATION	CORP
ABSTRACT	PAGES	CORPORATE AUTHOR	SUPL
DESCRIPTORS	CORPORATE AUTHOR	SUPPLEMENTARY NOTE	AB
IDENTIFIERS	SUPPLEMENTARY NOTE	ABSTRACT	DS
RELEVANCE RATING	ABSTRACT	DESCRIPTORS	ID
DATE RANGE	CBIAC SUBJECT KEYWORDS	IDENTIFIERS	RELEVANCE RATING
SENSITIVE EQUIPMENT	CBIAC IDENTIFIERS (KEYWORDS)	RELEVANCE RATING	DATE RANGE
SKIN AND PERSONAL EQUIPMENT	DTIC DESCRIPTORS (KEYWORDS)	FUNCTIONAL AREA	SENSITIVE EQUIPMENT
EQUIPMENT AND EXTERIOR EQUIPMENT	DTIC IDENTIFIERS (KEYWORDS)	DATE RANGE	SKIN AND PERSONAL EQUIPMENT
INTERIOR EQUIPMENT	AUTHOR KEYWORDS	SENSITIVE EQUIPMENT	EQUIPMENT AND EXTERIOR EQUIPMENT
FIXED SITE	TASK KEYWORDS	SKIN AND PERSONAL EQUIPMENT	INTERIOR EQUIPMENT
DECONTAMINANT	RELEVANCE RATING	EQUIPMENT AND EXTERIOR EQUIPMENT	FIXED SITE
	DATE RANGE	INTERIOR EQUIPMENT	DECONTAMINANT
	SENSITIVE EQUIPMENT	FIXED SITE	
	SKIN AND PERSONAL EQUIPMENT	DECONTAMINANT	
	EQUIPMENT AND EXTERIOR EQUIPMENT		
	INTERIOR EQUIPMENT		
	FIXED SITE		
	DECONTAMINANT		

APPENDIX C: Military and Commercial Decontamination Equipment Manufacturers

Military Decontamination Equipment Manufacturers

Company	Address	Phone
Aboukir Engineering Industries Co	Aboukir, Alexandria, Egypt	Tel: +20 (3) 560 1410 Fax:
ACMAT (Ateliers de Construction Mecanique de l'Antique)	Le Point de Jour, F44600 Saint Mazaire, France	Tel: +33 (2) 40 22 33 71 Fax: +33 (2) 40 66 30 96
AEROSTAR SA	Str Condorilor nr 9, Cod, R-5500 Bacau, Romania	Tel: +40 (34) 141885 Fax: +40 (34) 161113
Alfred Karcher GmbH & Co.	Alfred-Karcher-Strasse 28-40, D-71364 Winnenden, Germany	Tel: +49 (7195) 142262 Fax: +49 (7195) 142780
All-Bann Enterprises Inc.	2727 Coronado Street Anaheim, CA 92806, USA	Tel: +1 (714) 630 7711 Fax: +1 (714) 630 3102
Anachemia Canada Inc	PO Box 147 Lachine, Quebec, Canada H8S 4A7	Tel: +1 (514) 489 5711 Fax: +1 (514) 363 5281
Bachmann SA	69 Avenue Danielle Casanova P.O. Box 15, F94201 Ivry-sur-Seine, France	Tel: +33 (5) 46 72 42 69 Fax: +33 (1) 46 58 91 79
Birchmeier & Cie AG	CH-5444 Kunten Switzerland	Tel: +41 (56) 960121 Fax: +41 (56) 964932
CKD Blansko, Plc	Division 4 Letovice Czech Republic	Tel: +42 (501) 935794 Fax: +42 (501) 935177
Cristanini SpA	1-37010 Rrivoli (Verona), Italy.	Tel: +39 (45) 626 9400 Fax: +39 (45) 626 9411
Defence and Civil Applications Group, Daimler-Benz Aerospace AG	8 Friedrichshafen, D-88039 Lake Constance, Germany	Tel: +49 (7545) 81253 Fax: +49 (7545) 86596
DEW Engineering and Development Limited	3429 Hawthorne Road Ottawa, Ontario, Canada K1G 4G2	Tel: +1 (613) 736 5100 Fax: +1 (613) 736 1348
Edgewood Research, Development and Engineering Center	Aberdeen Proving Ground MD 21010-5423, USA	Tel: +1 (410) 436 5391 Fax: +1 (410) 436 2014
ENGESA Engenheiros Espacializados SA	Avenida Tucunare 125/211 PO Box 152/154, 06400 Barueri Sao Paulo, Brazil	Tel: +55 (11) 421 4711 Fax: +55 (11) 421 4445
Engineered Air Systems Inc.	1270 N Price Road St Louis, MO 63132, USA	Tel: +1 (314) 993 5880 Fax: +1 (314) 567 4052
EST s r o	584 01 Ledec nad Sazavou, Czech Republic	Tel: +42 (452) 3420 Fax: +42 (452) 4102
HAZMAT Protective Systems (Pty) Limited	PO Box 2177, Silverton Pretoria, 0127, South Africa	Tel: +27 (12) 665 0788 Fax: +27 (12) 665 0789
Hughes Safety Showers	Whitefield Road, Bredbury, Stockport, Cheshire, SK6 2SS, UK	Tel: +44 (161) 430 6618 Fax: +44 (161) 430 7928
J Blaschke wehrtechnik GmbH, Wienerbergestrasse	42-44, A-1120 Vienna, Austria	Tel: +43 (1) 810 09 09 Fax: +43 (1) 810 09 09 33
Karl H. Hoie & Co. A/S	Storgt. 37, N-0182 Oslo, Norway	Tel: +47 2220 4779 Fax: +47 2220 2891
Kintex	PO Box 209, 66 James Boucher Street 1407 Sofia, Bulgaria	Tel: +359 (2) 662311 Fax: +359 (2) 658191
Kraneks Engineering Co.	Settlement Mineevo, 153007 Ivanovo Russian Federation	Tel: Fax:
Minimax GmbH	Minimaxstrasse 1, D-72574 Bad Urach, Germany	Tel: +49 (7125) 154133 Fax: +49 (7125) 154100

Military Decontamination Equipment Manufacturers

Company	Address	Phone
NBCD Systems	40 rue de l'Echiquer F-75010 Paris, France	Tel: +33 (1) 42 47 03 14 Fax: +33 (1) 47 70 23 71
Ocher Engineering Co.	1 Maliyshev Street, Ocher 617140 Perm Region, RFAS	Tel: Fax:
Odenwald-Werke Ritterbach GmbH (OWR)	D-74834 Elztal-Rittersbach, Germany	Tel: +49 (6293) 731 Fax: +49 (6293) 73219
Plysu PLC	120 Station Rd. Woburn Sands, Milton MK17 8SE UK	Tel: +(01 908) 582311 Fax: +(01908) 585450
Remploy Limited	415 Edgware Rd Cricklewood, London NW2 6LR, UK	Tel: +44 (181) 235 0500 Fax: +44 (181) 235 0501
Research Institute for Chemical Defence	PO Box 1044 Beijing, People's Republic of China	Not Available
Richmond Packaging (UK) Limited	New Road, Winsford, Cheshire CW7 2NY, UK	Tel: +44 1606 557422 Fax: +44 1606 861063
Rohm and Haas Co.	25500 Whitesell ST. Hayward, CA 94545	Tel: (510) 786-0100 Fax:
Rosvoorouzhenie	21 Gogolevsky Blvd., 119865 Moscow, RFAS	Tel: +7 (095) 202 6603 Fax: +7 (095) 202 4594
Svenska Cargo Forsaljings AB	Wismarsvagen 1, S-393 54 Kalmar, Sweden	Tel: +46 (480) 216 00 Fax: +46 (480) 155 20
TATRA	Stefannikova 1163, 742 21 Koprivnice Czech Republic	Tel: Fax:
TECHINIKA Foreign Trade Company	Budapest-Hungary, X, Salgotarjani..20 PO Box 125, H-1475 Budapest, Hungary	Tel: +36 (1) 114 3230 Fax: +36 (1) 113 4691
Tirrena SpA	Via del Quirinale 22 1-00187 Rome, Italy	Tel: +39 (6) 474 4100 Fax: +39 (6) 464309
Tovama Avtomobilov Motorjev	Maribor, Slovenia	N/A
Tradeways Limited	184 Duke of Gloucester Street Annapolis MD 21401, USA	Tel: +1 (410) 295 0813 Fax: +1 (410) 295 0821
Truetech	680 Elton Ave. Riverhead, NY 11901	Tel: (516) 727-8600 Fax:
Ventilatorverken	Bronsyxegatan 9, S-213 75 Malmo, Sweden	Tel: +46 (40) 229040 Fax: +46 (40) 947863
VOP 025 Novy Jicin, sp	742 42 Senov u Noveho Jicina, Czech Republic	Tel: +420 (656) 22919 Fax: +420 (656) 22961
Wojskowe Zakladyy Lotnicze NR 2	ul Szubiriska 107, PL-85-915 Bydgoszcz, Poland	Tel: +48 (22) 629 6396 Fax: +48 (22) 628 6356
Yugoimport-SDPR	PO Box 89, Bulevar umetnosti 2, YU-11070 Belgrade, Yugoslavia (Serbia and Montenegro)	Tel: +381 (0) 11 3112743 Fax: +381 (0) 11 3130263

Commercial Decontamination Equipment Manufacturers

Company	Address	Phone
Aero Tec Laboratories, Inc.	Spear Rd. Industrial Park, Dept. T Ramsey, NJ 07446-1251	Tel: (800) 526-5330 Fax: (201) 825-1962
Applied Surface Technologies	15 Hawthorne Drive, New Providence, NJ 07974	Tel: (908) 464-6675 Fax:
Burch Mfg. Co., Inc.	618-T 1st Ave. N., Box 876 Fort Dodge, IA 50501-3818	Tel: (515) 573-4136 Fax: (515) 573-4138
Container Products Corporation	112 North College Rd, P.O. Box 3767 Wilmington, NC 28406	Tel: (910) 392-6100 Fax: (910) 392-6778
Crest Ultrasonices	Scotch Road, P.O. Box 7266 Trenton, NJ 08628	Tel: (609) 883-4000 Fax: (609) 883-6452
Cryogenesis	2140-T Scranton Rd. Cleveland, OH 44113	Tel: (216) 696-8797 Fax: (216) 696-8794
Cryokinetics	P.O. Box 782183 Witchita, KS 67278-2183	Tel: (316) 681-0080 Fax: (316) 681-0330
HAZDecon Rentals & Sales, Inc.	810-T W. Alex Bell Rd. Dayton, OH 43459	Tel: (888) 800-3266 Fax: (937) 435-9197
Kyzen	430 Harding Industrial Dr. Nashville, TN 37211	Tel: (615) 831-0888 Fax: (603) 622-2937
Los Alamaos National Laboratory	P-24 Plasma Physics, M/SE526 Los Alamos, NM 87545	Tel: (505) 665-6157 Fax: (505) 665-3552
MITI Mfg., Inc.	3183 Hall Ave., Dept. T Grand Junction, CO 81504	Tel: (970) 434-9100 Fax: (970) 434-9200
Pentek Inc.	1026-T Fourth Ave., Dept. TR Coraopolis, PA 15108	Tel: (412) 262-0725 Fax: (412) 262-0731
RMC Medical, Inc.	3021-T Darnell Rd. Philadelphia, PA 19154	Tel: (215) 824-4100 Fax:
TRI/Austin, Inc.	9063 Bee Caves Rd. Austin, TX 78733-6201	Tel: (800) 973-3266 Fax: (512) 263-3530
Spilfyter	963 Ashwaubenon Street Green Bay, WI 54304	Tel: (414) 337-4944 Fax: (920) 337-6282
Vapormatt, Inc.	P.O. Box 1514-T Smithtown, NY 11787	Tel: (516) 862-6811 Fax: (516) 862-6857
Va-Tran Systems, Inc.	677 Anita Street, Suite A, Chula Vista, CA 91911	Tel: (619) 423-4555 Fax: (619) 423-4604
Western Emergency Equipment	P.O. Box 8844 Emeryville, CA 94662	Tel: (510) 525-5766 Fax: (510) 527-3129

APPENDIX D: Asian Market Survey

Name	Title	Company	Address	City	Country	Postal Code	Telephone	Fax
Graham J Wright	Principal Risk Engineer	BHP Petroleum Pty Ltd	120 Collins Street	Melbourne, Victoria	Australia	3000	03-9652-7194	03-9652-6723
Peter Richard	Karratha Base Manager	Bluewater Offshore Production Systems	Lot 1045 Anderson Road P.O. Box 822	Karratha, Western Australia	Australia	6714	091-44-2141	091-44-2570
Anil Chenane	Project Engineer	Flour Daniel Pty Ltd	The Gateway, 512 St Kilda Road	Melbourne, Victoria	Australia	3004	61-3-9258-6201	61-3-9258-6001
Gary J Jeffrey	Manager of Operations	Hudson Energy Limited	25 Ventnor Avenue	West Perth, Western Australia	Australia	6872	09-481-8555	09-481-8881
E. Dean Carson	Production Manager	Marathon Australia Petroleum Ltd	P.O. Box 5192 Hay Street East Primary Industry House 239 Adelaide Terrace	Perth, Western Australia	Australia	6000	61-9-325-1938	
Richard L. Stallings	Managing Director	West Australia Petroleum Pty. Ltd.	239 Adelaide Terrace G.P.O. Box C 1580	Perth, Western Australia	Australia	6001	09-325-2181	09-325-3441
Keith B. Gammie	Deputy Director Petroleum Division	Western Australia Department of Mines	100 Plain Street	East Perth, Western Australia	Australia	6004	09-222-3142	09-222-3515
Clive Winter	Materials Superintendent	Western Mining Corporation Limited	HBL House 28-42 Ventnor Ave	West Perth, Western Australia	Australia	6005	61-9-483-2444	61-9-483-3450
Dr. S. D. Yadav	General Manager R&D	Ajay Metachem Private Ltd	72-76, Mundhawa	Pune	India	411 036	0212-672035	0212-332936
V.D. Iyer	Jt. General Manager	Essar Oil Limited	Essar House, P.O. Box 7913 Mahalaxmi	Mumbai	India	400 034	91-22-495-0506	91-22-495-4310
Partha Sarathy		Larsen & Tubro Ltd	Powai Works Saki Vihar Road PO Box 8901	Mumbai	India	400 072	91-22-578-1401 x3104	91-22-578-3005
Dr. R.A. Mashelkar	Director	National Chemical Laboratory		Pune	India	411 008	336-451	0212-330-233
P. K. Datta	Safety & Environmental Management	Oil & Natural Gas Commission	Bombay Regional Business Centre 5th Floor, Arcadia Nariman Point	Mumbai	India	400 021	202-01-15	202-79-36
Mike R. Wilson	Manager Facilities Engineering	Atlantic Richfield Indonesia Inc.	PANIN Bank Building, 2nd Floor Jl. Jendral Sudirman, Senayan P.O. Box 1093	Jakarta	Indonesia	10010	7202746	710103

Name	Title	Company	Address	City	Country	Postal Code	Telephone	Fax
Thomas E. Bundy	Project Development Manager	Conoco Indonesia Inc.	Midia Tower 3rd-6th Floor Jl. Jend. Gatot Subroto Kav. 9-11	Jakarta	Indonesia	12930	62-021-513-770	62-021-517-658
Inder Sing		P. T. Inconeco	Prince Centre Lantai XI Jl. Jenderal Soedirman No. 3-4	Jakarta	Indonesia		575-0455	572-2437
Edward I. Buckmuhl	Construction Manager	Unocal Indonesia, Ltd.	Ratu Plaza Office Tower - 7th Floor P.O. Box 1364 Jl. Jendral Sudirman, Senayan	Jakarta	Indonesia	10012	735-7344	720-4459
Toshiya Mizuno	Deputy Manager Project Engineering	Arabian Oil Company, Ltd	3-3, Marunouchi 3-Chome, Chiyoda-Ku	Tokyo	Japan	100	3214-4316	3214-7015
Takeshi Sujimoto	Process Engineer	Hitachi Engineering Co., Ltd.	17-24 Shinden-cho	Chuo-ku, Chiba	Japan	260	043-244-2101	043-244-2021
Yoshiaki Iizuka	Senior Manager Safety and Environment Department	Mitsubishi Kasei Corporation	1000, Kamoshida-cho Midori-ku	Yokohama	Japan	227	045-963-3055	045-963-3932
Yugi Sugimoto	Research & Knowledge Team	Mitsubishi Corporation	Marunouchi Mitsui Building 2F 2-2, Marunouchi 2-Chome, Chiyoda-ku	Tokyo	Japan	100-86	81-3-3210-7322	81-3-5210-7557
Dr. Noboru Yagi	Chief Specialist Environment & Safety Department	Mitsui Toatsu Chemicals, Inc.	2-5, Kasumigaseki 3-Chome Chiyoda-ku	Tokyo	Japan	100	03-3592-4385	03-3592-4265
Koji Okada	Assistant Manager	Osaka Gas Co., Ltd	5-19-9, Torishima Konohana-ku	Osaka	Japan	554	81-6-465-4561	81-6-464-1305
O Kageyama	Manager, Environmental Management Section	Sekisui Chemical Co., Ltd.	2-4-4, Nishitenmanju, Kita-ku	Osaka	Japan	530	81-6-365-4151	81-6-365-4374
Isao Hirata	Deputy Manager Environment & Safety Dept	Sumitomo Chemical Co., Ltd	27-1, Shinkawa 2-chome, Chuo-ku	Tokyo	Japan	104	81-3-5543-4196	81-3-5543-5908
Teruo Mitsumori	Manager	The Society of Chemical Engineers, Japan	Kyoritsu Building 4-6-19 Kohinata, Bunkyo-ku	Tokyo	Japan	112	81-3-3943-3527	81-3-3943-3530
Masahiko Tsuchiya	Senior Engineer	Toyo Engineering Corporation	8-1, Akanehama 2-chome, Narashino-shi	Chiba	Japan	275	81-474-54-1192	81-474-54-1821

Name	Title	Company	Address	City	Country	Postal Code	Telephone	Fax
Robert M. Quintos	Senior Engineer	American Bureau of Shipping	9th Floor Dong Ju Bldg. P.O. Box 171	Pusan	Korea	600-015	051-469-8171/5	051-462-4830
Jesus Aguirre	Construction Superintendent	Caltex Shipping Company	Samsung Koje Shipyard 530 Jangpyung-Ri Shinhyun-Up	Koje-Gun, Kyungnam	Korea	656-800	0558-30-3539	0558-32-2436
Jong Ju Park	Senior Engineer	Daelim Engineering Co., Ltd	17-5, Yoido-dong, Youngdungpo-ku	Seoul	Korea	150-010	82-2-369-5495	82-2-761-2571
Soon-nak Hong	Fire & Safety Supervisor	Hanwha Energy Co., Ltd.	100, Wonchang-Dong, Seo-ku	Inchon	Korea		032-570-5361	032-572-4575
Y. S. Kim	General Manager Fire & Safety Team	Honam Oil Refinery Co., Ltd	Lucky-Goldstar Twin Towers 20, Yoido-Dong, Youngdungpo-gu	Seoul	Korea	150-721	787-6309	785-5333
Moo-Ku Choi	Assistant Manager	Korea Industrial Safety Corporation	34-5 Kusan-Dong, Bupyung-gu	Inchon	Korea	403-120	82-32-5100-692	82-32-5129
Young-ok Kim	President Korea Branch	Olin Corporation	80-6 Soosong-Dong (Sukmun Bldg) Chongro-ku	Seoul	Korea	110-140	82-2-737-2840	82-2-730-7367
Y. S. Kim	Manager/Risk Dept	Procter & Gamble Korea, Inc	321-5 Chon-Heung Ri, Sunggur-Eup	Chonan-City, Choongnam	Korea		82-417-559-0033	82-417-553-0101
S. K. Lee	Safety Manager	Samsung Fine Chemicals Co., Ltd	190, Yeo Chun-Dong, Nam-ku	Ulsan, Kyungnam	Korea	680-090	82-522-70-6641	82-522-60-4610
D. S. Kim	Supervisor	SsangYong Oil Refining Co., Ltd	360 Samsan-Ri, Onsan-Myun, Uljo-gu	Ulsan, Kyungnam	Korea	689-890	82-522-31-2250	82-522-39-2118
J. O. Choi	PHA General Manager	Yukong Ltd	PSM Team Ulsan Complex P.O. Box 4	Ulsan, Kyungnam	Korea		82-522-70-2174	82-522-74-1597
Rosli B. Hj. Hasan	Director Urban Services Department	City of Kuala Lumpur	City Hall, Km. 4 Jalan Cheras	Kuala Lumpur	Malaysia	56100	934-5855	933-5578
John Brian Anthony	Safety Environmental Manager	Colgate-Palmolive (M) SDN BHD	P.O. Box 11076	Kuala Lumpur	Malaysia	50734	60-3-756-5544 ext 515	60-3-757-6314

Name	Title	Company	Address	City	Country	Postal Code	Telephone	Fax
Af. B. Abd. Kadir	Occupational Safety & Health Officer	Malaysian Department of Occupation Safety and Health	10th, 15th & 22nd Floor Wisma KWSA, Jalan Kg Attap	Kuala Lumpur	Malaysia	50534	03-273-5208 ext. 271	03-273-5432
Hong Kee Kok	Executive Secretary	Malaysian National Institute of Occupational Safety and Health	Lot 1-3 Bangunan BNH Off Jalan Semantan, Damansara Heights	Kuala Lumpur	Malaysia	50490	03-253-1961	03-253-1962
Dr. Foo Say Moo	Head, Environment	Petronas Research & Scientific Services SDN BHP	Lot 1026, Bangi Industrial Estate 54300 Hulu Klang	Selangor Darul Ehsan	Malaysia		60-3-407-1022	60-3-408-7472
James Kelleh Ajen	Environmental Affairs Manager	Shell Malaysia Trading Sdn Bhd	BangunanShell Malaysia Off Jalan Semantan Damansara Heights	Kuala Lumpur	Malaysia	50490	60-3-251-2600	60-3-251-3063
Robert Phelps		W. Cummings Materials		Kuala Lumpur	Malaysia		60-3-252-4421	
Li Xiang	Engineer	Nanhai West Oil Corp, CNOOC	P.O. Box 11, Potou Zhanjiang	Guangdong	PRC	524057	950-835 Ext 50314	339-434
Terry A. Holman	Country Manager	American Bureau of Shipping	7th Floor, Srithepthai Building 109 Bangna - Trat Road K M 2.5	Bangkok	Thailand	10260	662-535-3420-7	662-393-2419
Michael G. Keogh	Lead Safety Engineer (Environmental Protection)	Abu Dhabi Marine Operating Company	PO Box 303	Abu Dhabi	UAE		6064563	5064993
William	Vice President	American Bureau of Shipping		Dubai	UAE			
Hamdan Khalifa Al-Sheer	Asst. Head Environmental Protection & Safety Section Health Department	Dubai Municipality	P.O. Box 67	Dubai	UAE		225-763	270-160
Niaz A. Khan	Senior Environmental Officer	Jebel Ali Free Zone Authority	P.O. Box 17000	Dubai	UAE		971-4-814-0252	971-4-815-5227
Abdulla A. J. Makki	Head of Marine Operations	Zadco Development Company	P.O. Box 46808	Abu Dhabi	UAE		605-2211	559-443

APPENDIX E: Listing of Customized Codes

The customized codes fill three fundamental roles:

1) They define the conceptual framework used for naming the boundaries of interest and for structuring a picture of how the data is to be organized.
2) They provide the equivalent of a very detailed outline of the information - which permits rapid selection of a particular subject or set of subjects (the codes are searchable or can be "read out" electronically into a large number of temporary sets for purposes of quicker analysis)
3) They provide the audit trail connecting the synthesized summaries back to the original documentation. This permits the assembly of a specialized "book" of the original source material, which was deemed relevant to this particular subject. Since that detailed database is protected by Copyrights held by the original contributors of electronic database providers, it cannot be distributed in electronic form. Single copies of printouts may be provided upon request. Such printouts will be noted as copyrighted and as not to be used for further distribution.

A sample code is
ZZTECDECON:SUB:AIR-ATMOSPHERE;EVE:ACCIDENT-EMISSIONS/CHE:MULTI . The structure and definitions reflected in this code are outlined below.

The coding structure for this project is designed to classify the data to reflect the industrial and commercial contexts in which biological and/or chemical contamination has occurred. It is hierarchical; moving from left to right. Each level of the code is separated by a "marker" and an abbreviation that defines it in the following order:

Level 1. ZZTECDECON Defines the <u>general domain of interest</u> as being Technologies for Decontamination.

Level 2. :SUB:AIR-ATMOSPHERE Defines the <u>substrate</u> on which or in which the contamination is experienced. There are two level of specificity. In this case the broadest classification is in the Air in the open atmosphere - as distinguished from say enclosed air within buildings.

Level 3. ;EVE:ACCIDENT-EMISSIONS Defines the type of <u>contamination event</u>. In this case the event was an accident in which an emission occurred.

Level 4. /CHE:MULTI defines the <u>type of contaminant</u>. In this event the emissions were multiple chemicals.

Therefore, when we look at this code we "read" it as a compartment of information that contains a synthesis of contamination experiences involving <u>Technologies for decontamination of multiple chemicals that accidentally escaped into the outside atmosphere.</u>

Since Level 1 is common to all codes it is omitted in the following table which is arranged in alphabetical order beginning with Level 2 - the substrates. This permits one to read quickly down the list to glean an overall picture of the entire structure of the underlying data. The table is arranged in newspaper type columns. The codes listed here correspond exactly to the <u>code field</u> contained in the accompanying CDROM in which the synthesized intelligence is found.

sub:air-atmosphere;eve:accident-emissions/che:multi
sub:air-atmosphere;eve:accident-explosion/che:multi
sub:air-atmosphere;eve:accident-explosion/nuc:radiation
sub:air-atmosphere;eve:accident-fire/che:multi
sub:air-atmosphere;eve:accident-release/che:multi
sub:air-atmosphere;eve:accident-release/nuc:radiation
sub:air-atmosphere;eve:regulatory-emissions/che:multi
sub:air-atmosphere;eve:sensing-fallout/nuc:radiation
sub:air-atmosphere;eve:treatment-emissions/bio:pathogens
sub:air-atmosphere;eve:treatment-emissions/che:multi
sub:air-atmosphere;eve:treatment-emissions/nuc:radiation
sub:air-gases;eve:treatment-material/che:toxins
sub:air-gases;eve:treatment-waste/che:toxins
sub:air-internal;eve:accident-byproduct/che:methanol
sub:air-internal;eve:accident-leak/che:multi
sub:asphalt-material;eve:cleaning-surface/che:multi
sub:building-construction materials;eve:treatment-research/che:multi#
sub:building-construction
materials;eve:treatment-timber/bio:microbes
sub:building-exterior;eve:cleaning-concrete/che:multi
sub:building-exterior;eve:treatment-wood/che:nerve gas
sub:building-general;eve:cleaning-exterior/che:multi
sub:building-general;eve:protection-building/che:multi
sub:building-general;eve:treatment-building/nuc:radiation
sub:building-general;eve:weapons-military/che:toxins
sub:building-internal;eve:accident-leak/che:multi
sub:building-internal;eve:accident-release/che:multi
sub:building-internal;eve:cleaning-building/che:asbestos
sub:building-internal;eve:cleaning-building/nuc:radiation
sub:building-internal;eve:equipment-gases/che:multi
sub:building-internal;eve:treatment-building/che:asbestos
sub:building-internal;eve:treatment-material/che:asbestos
sub:building-internal;eve:treatment-surface/bio:microbes
sub:building-material;eve:treatment-external/che:nerve gas
sub:building-material;eve:treatment-waste/che:multi
sub:building-material;eve:weapons-military/che:nerve gas
sub:building-surfaces;eve:treatment-concrete/che:nerve gas
sub:cloth-material;eve:cleaning-cloth/che:hydrocarbons
sub:cloth-material;eve:cleaning-cloth/nuc:radiation
sub:cloth-material;eve:treatment-cloth/che:hydrocarbons
sub:cloth-material;eve:treatment-cloth/nuc:radiation
sub:clothing-material;eve:treatment-cleaning/bio:bacteria
sub:clothing-material;eve:treatment-cleaning/che:oil
sub:clothing-material;eve:treatment-repair/che:multi
sub:clothing-military;eve:weapons-military/che:nerve gas
sub:clothing-military;eve:weapons-terrorism/che:nerve gas
sub:concrete-building;eve:protection-internal/bio:microbes
sub:concrete-exterior;eve:protection-surface/che:multi
sub:concrete-exterior;eve:treatment-surface/che:multi
sub:concrete-exterior;eve:treatment-surface/nuc:radiation
sub:concrete-external;eve:cleaning-concrete/che:petrochemicals
sub:concrete-external;eve:cleaning-concrete/nuc:radiation
sub:concrete-external;eve:treatment-concrete/che:petrochemicals
sub:concrete-external;eve:treatment-concrete/nuc:radiation
sub:concrete-material;eve:surface-repair/che:multi
sub:concrete-storage tank liner;eve:deterioration-concrete/nuc:radiat
sub:concrete-surface;eve:accident-spill/che:jet fuel
sub:concrete-surface;eve:accident-transport/nuc:radiation
sub:concrete-surface;eve:cleaning-waste/che:multi
sub:concrete-surface;eve:protection-hazard/che:multi
sub:equipment-electronics;eve:cleaning-exterior/che:multi
sub:equipment-electronics;eve:cleaning-gases/che:multi
sub:equipment-electronics;eve:treatment-equipment/che:metals
sub:equipment-electronics;eve:treatment-equipment/che:ozone
sub:air-internal;eve:accident-release/nuc:radiation
sub:air-internal;eve:equipment-general/che:multi
sub:air-internal;eve:protection-personnel/che:asbestos
sub:air-internal;eve:protection-personnel/che:multi
sub:air-internal;eve:space travel-military/che:contaminants
sub:air-internal;eve:treatment-building/che:multi
sub:air-internal;eve:treatment-building/nuc:radiation
sub:air-internal;eve:treatment-gases/che:nerve gas
sub:air-internal;eve:treatment-waste/che:multi
sub:air-internal;eve:ventilation-building/che:multi
sub:air-internal;eve:ventilation-building/che:odors
sub:air-internal;eve:ventilation-gases/che:multi
sub:air-internal;eve:ventilation-humidity/che:moisture
sub:air-internal;eve:ventilation-safety/bio:bacteria
sub:air-internal;eve:ventilation-safety/che:multi
sub:equipment-electronics;eve:treatment-gases/che:multi
sub:equipment-external;eve:cleaning-equipment/nuc:radiation
sub:equipment-external;eve:treatment-equipment/che:multi
sub:equipment-external;eve:treatment-equipment/nuc:radiation
sub:equipment-external;eve:treatment-waste/che:soda ash
sub:equipment-gauges;eve:treatment-tubes/che:vapors
sub:equipment-general;eve:cleaning-fluids/che:multi
sub:equipment-general;eve:cleaning-surface/che:multi
sub:equipment-general;eve:corrosion-steel/che:multi
sub:equipment-general;eve:regulatory-safety/che:multi
sub:equipment-general;eve:treatment-equipment/che:multi
sub:equipment-general;eve:weapons-military/che:nerve gas
sub:equipment-general;eve:weapons-terrorism/che:liquid metal
embrittl
sub:equipment-material;eve:treatment-waste/che:chlorine
sub:equipment-material;eve:treatment-waste/che:hydrocarbons
sub:equipment-material;eve:treatment-waste/che:pcb
sub:equipment-military;eve:treatment-equipment/che:nerve gas
sub:equipment-plastic;eve:cleaning-plastic/che:multi
sub:equipment-plastic;eve:treatment-equipment/che:multi
sub:equipment-plastic;eve:treatment-equipment/che:toxins
sub:equipment-plastic;eve:treatment-plastic/che:multi
sub:equipment-plastic;eve:treatment-waste/che:multi
sub:equipment-process;eve:cracking-pipes/che:gases
sub:equipment-process;eve:treatment-waste/che:nitrous oxide
sub:equipment-process;eve:treatment-waste/che:resin
sub:equipment-sensors;eve:weapons-military/che:toxins
sub:equipment-telephones;eve:weapons-terrorism/che:liquid metal
embri
sub:equipment-tubes;eve:treatment-gauges/che:oil vapors
sub:agriculture-crop;eve:treatment-raw material/bio:pathogens
sub:agriculture-crop;eve:treatment-raw material/che:pesticides
sub:agriculture-crop;eve:treatment-soil/che:multi
sub:agriculture-foodcrop;eve:cleaning-raw material/che:multi
sub:agriculture-foodcrop;eve:treatment-product/bio:pathogens
sub:agriculture-foodcrop;eve:treatment-product/che:multi
sub:agriculture-foodcrop;eve:treatment-product/che:polyethylene
film#
sub:agriculture-foodcrop;eve:treatment-raw material/che:multi
sub:air-atmosphere;eve:treatment-waste/che:toxins
sub:air-internal;eve:ventilation-building/che:toxins
sub:fluid-material;eve:oil-recycling/che:hydrocarbons
sub:fluid-material;eve:packaging-fluid/che:multi
sub:fluid-material;eve:treatment-waste/che:multi
sub:fluid-material;eve:treatment-waste/nuc:radiation
sub:fluid-material;eve:weapons-military/che:nerve gas
sub:fluid-waste;eve:treatment-storage tank/nuc:radiation
sub:fluid-waste;eve:treatment-waste/che:nitric acid
sub:fluid-waste;eve:treatment-waste/nuc:radiation
sub:glass-material;eve:treatment-product/che:multi
sub:masonry-external;eve:cleaning-surface/che:dirt
sub:masonry-external;eve:cleaning-surface/nuc:radiation
sub:masonry-external;eve:treatment-surface/che:multi
sub:masonry-external;eve:treatment-surface/nuc:radiation
sub:medicine-research;eve:treatment-concentration/che:heavy metals
sub:medicine-research;eve:treatment-waste/che:chlorine
sub:metal-cylinders;eve:sensing-ultrasonic/che:gases

sub:metal-external;eve:cleaning-metal/che:toxins
sub:metal-external;eve:corrosion-steel/che:oxide scale
sub:metal-external;eve:treatment-metal/che:toxins
sub:metal-external;eve:weapons-military/che:nerve gas
sub:metal-external;eve:weapons-terrorism/che:toxins
sub:metal-general;eve:treatment-metal/che:dirt
sub:metal-general;eve:treatment-metal/che:toxins
sub:metal-material;eve:corrosion-steel/che:hydrocarbons
sub:metal-material;eve:treatment-waste/che:multi
sub:metal-material;eve:weapons-terrorism/che:liquid metal embrittleme
sub:metal-pipes;eve:accident-leak/nuc:radiation
sub:metal-pipes;eve:accident-weld failure/nuc:radiation
sub:metal-pipes;eve:cracking-pipes/nuc:radiation
sub:metal-storage tank;eve:accident-leak/che:multi
sub:metal-storage tank;eve:accident-leak/nuc:radiation
sub:metal-storage tank;eve:cleaning-metal/che:toxins
sub:metal-storage tank;eve:cleaning-storage tank/nuc:radiation
sub:metal-storage tank;eve:deterioration-metal/nuc:radiation
sub:metal-storage tank;eve:treatment-metal/che:petrochemicals
sub:metal-storage tank;eve:treatment-metal/che:toxins
sub:metal-storage tankers;eve:treatment-waste/che:hydrocarbons
sub:mfg-automobile;eve:treatment-emissions/che:carbon monoxide
sub:mfg-chemical;eve:accident-explosion/che:hydrocarbons
sub:mfg-chemical;eve:accident-explosion/che:multi
sub:mfg-chemical;eve:accident-explosion/nuc:radiation
sub:mfg-chemical;eve:accident-fire/che:multi
sub:mfg-chemical;eve:accident-fire/che:nylon
sub:mfg-chemical;eve:accident-leak/che:multi
sub:mfg-chemical;eve:accident-leak/che:toxins
sub:mfg-chemical;eve:accident-prevention/che:multi
sub:mfg-chemical;eve:accident-simulation/che:multi
sub:mfg-chemical;eve:accident-spill/che:multi
sub:mfg-chemical;eve:conversion-weapons/che:nerve gas
sub:mfg-chemical;eve:conversion-weapons/che:toxins
sub:mfg-chemical;eve:protection-personnel/che:multi
sub:mfg-chemical;eve:regulatory-labeling/che:toxins
sub:mfg-chemical;eve:regulatory-process/che:toxins
sub:mfg-chemical;eve:treatment-product/che:multi
sub:mfg-chemical;eve:treatment-site/che:multi
sub:mfg-chemical;eve:treatment-waste/che:multi
sub:mfg-chemical;eve:treatment-waste/che:oxides
sub:mfg-chemical;eve:treatment-waste/che:pcb
sub:mfg-chemical;eve:treatment-waste/che:pesticides
sub:mfg-chemical;eve:treatment-waste/che:toxins
sub:mfg-chemical;eve:treatment-weapons conversion/che:multi
sub:mfg-chemical;eve:ventilation-building/che:multi
sub:mfg-chemical;eve:weapons-terrorism/che:toxins
sub:site-landfill;eve:sensing-corrosion/che:multi
sub:site-landfill;eve:sensing-temp/che:multi
sub:site-landfill;eve:treatment-waste/bio:pathogens
sub:site-landfill;eve:treatment-waste/che:acid
sub:site-landfill;eve:treatment-waste/che:alpechin
sub:site-landfill;eve:treatment-waste/che:aromatics
sub:site-landfill;eve:treatment-waste/che:cyanide
sub:site-landfill;eve:treatment-waste/che:explosives
sub:site-landfill;eve:treatment-waste/che:gases
sub:site-landfill;eve:treatment-waste/che:halocarbons
sub:site-landfill;eve:treatment-waste/che:heavy metals
sub:site-landfill;eve:treatment-waste/che:heavymetals
sub:site-landfill;eve:treatment-waste/che:hrdmatics
sub:site-landfill;eve:treatment-waste/che:hydrocarbons
sub:site-landfill;eve:treatment-waste/che:inorganic
sub:site-landfill;eve:treatment-waste/che:meterocycles
sub:site-landfill;eve:treatment-waste/che:multi
sub:site-landfill;eve:treatment-waste/che:organic
sub:site-landfill;eve:treatment-waste/che:petrochem
sub:site-landfill;eve:treatment-waste/che:phenolics
sub:site-landfill;eve:treatment-waste/che:solvents
sub:site-landfill;eve:treatment-waste/che:toxins
sub:site-landfill;eve:treatment-waste/che:volitileorganics
sub:site-landfill;eve:treatment-waste/nuc:radiation
sub:site-superfund;eve:regulatory-treatment/che:multi
sub:site-superfund;eve:treatment-facility/che:multi
sub:site-superfund;eve:treatment-facility/che:toxins
sub:site-superfund;eve:treatment-waste/bio:pathogens
sub:site-superfund;eve:treatment-waste/che:aromatic hydrocarbons
sub:site-superfund;eve:treatment-waste/che:cyanide
sub:site-superfund;eve:treatment-waste/che:gases
sub:site-superfund;eve:treatment-waste/che:solvents
sub:site-superfund;eve:treatment-waste/che:toxins
sub:site-superfund;eve:treatment-waste/che:volatile organic compunds#
sub:site-superfund;eve:treatment-waste/nuc:radiation
sub:site-agriculture;eve:accident-storage/che:multi
sub:site-agriculture;eve:protection-personnel/che:herbicides
sub:site-agriculture;eve:protection-personnel/che:pesticides
sub:site-agriculture;eve:seepage-storage tanks/che:petrochemicals
sub:site-agriculture;eve:treatment-waste/che:alpechin
sub:site-agriculture;eve:treatment-waste/che:atrazine
sub:site-agriculture;eve:treatment-waste/che:herbicides
sub:site-agriculture;eve:treatment-waste/che:pesticides
sub:site-agriculture;eve:treatment-waste/che:toxins
sub:site-airfield;eve:accident-spill/che:multi
sub:site-airfield;eve:cleaning-external/che:multi
sub:site-airfield;eve:treatment-external/che:multi
sub:site-airfield;eve:treatment-waste/che:multi
sub:vehicle-aircraft;eve:accident-prevention/che:multi
sub:vehicle-aircraft;eve:treatment-internal/che:multi
sub:vehicle-general;eve:accident-crash/nuc:radiation
sub:vehicle-general;eve:accident-transport/nuc:radiation
sub:vehicle-general;eve:transport-hazardous/che:herbicides
sub:vehicle-general;eve:transport-hazardous/che:toxins
sub:vehicle-general;eve:transport-hazardous/nuc:radiation
sub:vehicle-general;eve:transport-safety/che:multi
sub:vehicle-general;eve:weapons-terrorism/che:liquid metal embrittlem
sub:vehicle-internal;eve:treatment-mfg/che:multi
sub:vehicle-rail;eve:weapons-terrorism/che:liquid metal embrittlement
sub:vehicle-safety;eve:transport-loading/che:equipment
sub:vehicle-ship;eve:acciccnt-spill/che:petrochemicals
sub:vehicle-ship;eve:cleaning-exterior/che:multi
sub:vehicle-ship;eve:transport-safety/che:multi
sub:vehicle-ship;eve:treatment-waste/che:copper
sub:vehicle-ship;eve:treatment-waste/che:trybutyltin
sub:personnel-blood;eve:accident-exposure/bio:pathogens
sub:personnel-blood;eve:accident-exposure/che:multi
sub:personnel-clothing;eve:treatment-equipment/che:toxins
sub:personnel-general;eve:accident-exposure/bio:pathogens
sub:personnel-general;eve:accident-exposure/che:toxins
sub:personnel-general;eve:accident-exposure/nuc:radiation
sub:personnel-general;eve:accident-leak/nuc:radiation
sub:personnel-general;eve:accident-spill/che:multi
sub:personnel-general;eve:protection-personnel/che:multi
sub:personnel-general;eve:treatment-personnel/che:toxins
sub:personnel-general;eve:weapons-military/bio:pathogens
sub:personnel-general;eve:weapons-military/che:toxins
sub:personnel-general;eve:weapons-terrorism/bio:pathogens
sub:personnel-general;eve:weapons-terrorism/che:toxins
sub:personnel-lung;eve:accident-exposure/che:toxins
sub:personnel-military;eve:clothing-protection/che:multi
sub:personnel-military;eve:weapons-military/bio:pathogens
sub:personnel-military;eve:weapons-military/che:g agents
sub:personnel-military;eve:weapons-military/che:multi
sub:personnel-military;eve:weapons-military/che:nerve gas
sub:personnel-military;eve:weapons-military/che:toxins
sub:personnel-skin;eve:accident-exposure/bio:pathogens
sub:personnel-skin;eve:accident-exposure/che:toxins
sub:personnel-skin;eve:clothing-protection/che:herbicides
sub:personnel-skin;eve:medicine-safety/bio:pathogens

sub:mfg-clothing;eve:accident-raw material/bio:pathogens
sub:mfg-clothing;eve:protection-product/che:nerve gas
sub:mfg-clothing;eve:treatment-equipment/che:multi
sub:mfg-clothing;eve:treatment-raw material/che:toxins
sub:mfg-clothing;eve:treatment-water/che:multi
sub:mfg-electronics;eve:cleaning-surface/che:metals
sub:mfg-electronics;eve:process-controlled environment/che:gases
sub:mfg-electronics;eve:process-gases/che:multi
sub:mfg-electronics;eve:treatment-equipment/che:multi
sub:mfg-electronics;eve:treatment-gases/che:multi
sub:mfg-electronics;eve:treatment-product/che:multi
sub:mfg-electronics;eve:treatment-waste/che:acid
sub:mfg-electronics;eve:treatment-waste/che:metals
sub:mfg-equipment;eve:cleaning-product/che:scale
sub:mfg-equipment;eve:treatment-waste/che:multi
sub:mfg-extraction;eve:treatment-air/che:gases
sub:mfg-extraction;eve:treatment-waste/che:multi
sub:mfg-extraction;eve:ventilation-building/che:multi
sub:mfg-facility;eve:treatment-waste/che:toxins
sub:mfg-food;eve:accident-product/bio:pathogens
sub:mfg-food;eve:accident-product/che:toxins
sub:mfg-food;eve:accident-product/nuc:radiation
sub:mfg-food;eve:accident-raw material/bio:pathogens
sub:mfg-food;eve:cleaning-equipment/bio:bacteria
sub:mfg-food;eve:packaging-controlled environment/che:multi
sub:mfg-food;eve:packaging-internal/bio:pathogens
sub:mfg-food;eve:packaging-product/bio:pathogens
sub:mfg-food;eve:packaging-product/che:moisture
sub:mfg-food;eve:packaging-product/che:toxins
sub:mfg-food;eve:purif-water/che:toxins
sub:mfg-food;eve:sensing-product/bio:pathogens
sub:mfg-food;eve:sensing-raw material/bio:pathogens
sub:mfg-food;eve:sensing-raw material/che:toxins
sub:mfg-food;eve:treatment-product/bio:parasites
sub:mfg-food;eve:treatment-product/bio:pathogens
sub:mfg-food;eve:treatment-product/che:toxins
sub:mfg-food;eve:treatment-raw material/bio:pathogens
sub:mfg-food;eve:treatment-raw material/che:multi
sub:mfg-food;eve:treatment-raw material/nuc:radiation
sub:mfg-food;eve:treatment-waste/bio:pathogens
sub:mfg-petrochem;eve:accident-explosion/che:petroleum
sub:mfg-petrochem;eve:treatment-oil/bio:microbes
sub:mfg-petrochem;eve:treatment-waste/che:hydrocarbons
sub:mfg-petrochem;eve:treatment-waste/che:multi
sub:mfg-petroleum;eve:treatment-waste/che:hydrocarbons
sub:mfg-sensor;eve:treatment-waste/che:multi
sub:mfg-steel;eve:cleaning-equipment/che:multi
sub:mfg-steel;eve:treatment-product/che:multi
sub:mfg-steel;eve:treatment-product/nuc:radiation
sub:mfg-steel;eve:treatment-raw material/nuc:radiation
sub:mfg-steel;eve:treatment-waste/che:multi
sub:mfg-steel;eve:treatment-waste/nuc:radiation
sub:mfg-textile;eve:accident-raw material/bio:pathogens
sub:mfg-textile;eve:treatment-raw material/che:multi
sub:mfg-weapons;eve:protection-personnel/che:nerve gas
sub:mfg-weapons;eve:protection-personnel/che:toxins
sub:pipe-internal;eve:treatment-pipe/che:paint
sub:plastic-material;eve:treatment-waste/che:multi
sub:plastic-material;eve:treatment-waste/che:plastic
sub:sensor-military;eve:research-micro air vehicle/che:toxins
sub:site-mfg;eve:accident-prevention/bio:biomass
sub:site-mfg;eve:accident-spill/che:hydrocarbons
sub:site-mfg;eve:accident-spill/che:monoethanolinesludge
sub:site-mfg;eve:accident-spill/che:multi
sub:site-mfg;eve:protection-personnel/che:toxins
sub:site-mfg;eve:seepage-storage tank/che:hydrocarbons
sub:site-mfg;eve:seepage-storage tanks/che:petrochem
sub:site-mfg;eve:treatment-waste/che:chlorinated hydrocarbons
sub:site-mfg;eve:treatment-waste/che:chlorine
sub:site-mfg;eve:treatment-waste/che:heavy metals
sub:site-mfg;eve:treatment-waste/che:hydrocarbons
sub:site-mfg;eve:treatment-waste/che:inorganic
sub:site-mfg;eve:treatment-waste/che:metals
sub:site-mfg;eve:treatment-waste/che:multi
sub:site-mfg;eve:treatment-waste/che:nitroaromatics
sub:site-mfg;eve:treatment-waste/che:organic
sub:site-mfg;eve:treatment-waste/che:pah
sub:site-mfg;eve:treatment-waste/che:pesticides
sub:site-mfg;eve:treatment-waste/che:petroleum
sub:site-mfg;eve:treatment-waste/che:tnt
sub:site-mfg;eve:treatment-waste/che:toxins
sub:site-mfg;eve:treatment-waste/che:trichloroethylene
sub:site-mfg;eve:treatment-waste/nuc:radiation
sub:site-mfg;eve:treatment-weapons/nuc:radiation
sub:surface-concrete;eve:cleaning-concrete/bio:pathogens
sub:surface-external;eve:cleaning-concrete/bio:pathogens
sub:surface-external;eve:cleaning-surface/bio:microbes
sub:surface-general;eve:cleaning-surface/che:toxins
sub:surface-solid;eve:cleaning-surface/che:hydrocarbons
sub:surface-solid;eve:cleaning-surface/nuc:radiation
sub:surface-solid;eve:packaging-external/bio:bacteria
sub:surface-solid;eve:sampling-toxic soil/che:toxins
sub:surface-solid;eve:sensing-work site/bio:bacteria
sub:surface-solid;eve:treatment-general/che:nerve gas
sub:surface-solid;eve:treatment-metal/nuc:radiation
sub:surface-solid;eve:treatment-surface/che:hydrocarbons
sub:surface-solid;eve:treatment-surface/nuc:radiation
sub:surface-solid;eve:treatment-waste/che:heavy metals
sub:surface-solid;eve:treatment-waste/che:organochlorine
sub:surface-solid;eve:treatment-waste/nuc:radiation
sub:surface-solid;eve:treatment-wood/che:toxins
sub:surface-solid;eve:weapons-military/che:nerve gas
sub:surface-steel;eve:treatment-product/nuc:radiation
sub:surface-steel;eve:treatment-waste/che:multi
sub:water-drinking;eve:accident-leak/bio:pathogens
sub:water-drinking;eve:accident-leak/che:multi
sub:water-drinking;eve:accident-processing/che:floride
sub:water-drinking;eve:accident-seepage/che:multi
sub:water-drinking;eve:accident-spill/che:jet fuel
sub:water-drinking;eve:accident-spill/nuc:radiation
sub:water-drinking;eve:accident-treatment/bio:pathogens
sub:water-drinking;eve:purif-beverage/che:inorganic
sub:water-drinking;eve:purif-water plant/che:chloroethylenes
sub:water-drinking;eve:purif-water plant/che:fulvic acids
sub:water-drinking;eve:purif-water plant/che:hydrocarbons
sub:water-drinking;eve:purif-water plant/che:metals
sub:water-drinking;eve:purif-water plant/che:nitrates
sub:water-drinking;eve:purif-water plant/che:nitrogen
sub:water-drinking;eve:purif-water plant/che:ozone
sub:water-drinking;eve:purif-water plant/che:pesticides
sub:water-drinking;eve:purif-water plant/che:phosphorus
sub:water-drinking;eve:purif-water plant/che:toxins
sub:water-drinking;eve:purif-water/bio:pathogens
sub:water-drinking;eve:purif-water/che:hydrocarbons
sub:water-drinking;eve:purif-water/che:multi
sub:water-drinking;eve:purif-water/che:nitrate
sub:water-drinking;eve:purif-water/che:organic
sub:water-drinking;eve:purif-water/che:phosphorus
sub:water-fresh;eve:accident-leak/che:metals
sub:water-fresh;eve:accident-leak/che:toxins
sub:water-fresh;eve:accident-leak/nuc:radiation
sub:water-fresh;eve:purif-water plant/che:scale
sub:water-fresh;eve:purif-water/bio:algae
sub:water-fresh;eve:purif-water/che:heavy metals
sub:water-fresh;eve:purif-water/che:metals
sub:water-fresh;eve:purif-water/che:organic
sub:water-fresh;eve:purif-water/nuc:radiation
sub:water-fresh;eve:ventilation-safety/bio:bacteria
sub:water-fresh;eve:weapons-military/che:toxins
sub:water-general;eve:purif-water/che:organic

sub:water-salt;eve:purif-water/che:salt
sub:mfg-fuel;eve:cleaning-general/che:multi
sub:mfg-fuel;eve:treatment-equipment/che:multi
sub:mfg-fuel;eve:treatment-general/che:multi
sub:mfg-fuel;eve:treatment-product/che:multi
sub:mfg-gases;eve:treatment-emissions/che:hyrdrocarbons
sub:mfg-gases;eve:treatment-processing/che:multi
sub:mfg-gases;eve:treatment-product/che:multi
sub:mfg-gases;eve:treatment-waste/che:hydrocarbons
sub:mfg-gases;eve:treatment-waste/che:multi
sub:mfg-gases;eve:ventilation-safety/che:toxins
sub:mfg-general;eve:accident-explosion/che:multi
sub:mfg-general;eve:cleaning-equipment/che:multi
sub:mfg-general;eve:cleaning-metal/che:multi
sub:mfg-general;eve:protection-environment/che:multi
sub:mfg-general;eve:sensing-raw material/che:multi
sub:mfg-general;eve:treatment-product/che:multi
sub:mfg-general;eve:treatment-waste/che:multi
sub:mfg-general;eve:ventilation-safety/che:multi
sub:mfg-metals;eve:cleaning-equipment/bio:protein
sub:mfg-paint;eve:treatment-product/che:multi
sub:mfg-paint;eve:treatment-waste/che:multi
sub:mfg-pharmaceutical;eve:packaging-product/che:multi
sub:mfg-pharmaceutical;eve:testing-product/bio:bacteria
sub:mfg-pharmaceutical;eve:treatment-waste/bio:pathogens
sub:mfg-pharmaceutical;eve:treatment-waste/che:multi
sub:mfg-plastic;eve:treatment-waste/che:multi
sub:mfg-plating;eve:cleaning-surface/che:heavy metals
sub:mfg-powder;eve:packaging-product/che:multi
sub:mfg-pulp paper;eve:treatment-waste/che:multi
sub:mining-coal;eve:treatment-waste/che:metals
sub:mining-gold;eve:treatment-waste/che:cyanide
sub:packaging-external;eve:cleaning-material/che:multi
sub:packaging-material;eve:regulatory-chemical/che:multi
sub:packaging-material;eve:regulatory-process/che:multi
sub:packaging-material;eve:transport-general/che:multi
sub:site-facility;eve:accident-leak/che:multi
sub:site-facility;eve:accident-release/che:multi
sub:site-facility;eve:accident-spill/che:petrochem
sub:site-facility;eve:cleaning-general/che:multi
sub:site-facility;eve:research-radiation/nuc:radiation
sub:site-facility;eve:research-uptake/che:metals
sub:site-facility;eve:seepage-storage tanks/che:petrochem
sub:site-facility;eve:sensing-product/che:multi
sub:site-facility;eve:treatment-building/bio:pathogens
sub:site-facility;eve:treatment-construction materials/nuc:radiation#
sub:site-facility;eve:treatment-explosion/che:multi
sub:site-facility;eve:treatment-process contamination/bio:microbes
sub:site-facility;eve:treatment-storage/che:pcb
sub:site-facility;eve:treatment-waste/bio:microbes
sub:site-facility;eve:treatment-waste/bio:pathogens
sub:site-facility;eve:treatment-waste/che:aromatic hydrocarbons
sub:site-facility;eve:treatment-waste/che:g agents
sub:site-facility;eve:treatment-waste/che:heavy metals
sub:site-facility;eve:treatment-waste/che:inorganic
sub:site-facility;eve:treatment-waste/che:lead
sub:site-facility;eve:treatment-waste/che:multi
sub:site-facility;eve:treatment-waste/che:nerve gas
sub:site-facility;eve:treatment-waste/che:nitroaromatics
sub:site-facility;eve:treatment-waste/che:organic
sub:site-facility;eve:treatment-waste/che:pcb
sub:site-facility;eve:treatment-waste/che:pesticides
sub:site-facility;eve:treatment-waste/che:petrochem
sub:site-facility;eve:treatment-waste/che:phenols
sub:site-facility;eve:treatment-waste/che:tetrachloroethylene
sub:site-facility;eve:treatment-waste/che:toxins
sub:site-facility;eve:treatment-waste/che:trichloroethylene
sub:site-facility;eve:treatment-waste/che:trinitrotoluene
sub:site-facility;eve:treatment-waste/nuc:radiation
sub:site-medical;eve:cleaning-equipment/bio:pathogens
sub:site-medical;eve:cleaning-waste/bio:pathogens
sub:site-medical;eve:treatment-emissions/bio:pathogens
sub:site-medical;eve:treatment-waste/bio:pathogens
sub:site-metals;eve:treatment-waste/che:sulphur
sub:site-military;eve:accident-transport/nuc:radiation
sub:site-military;eve:treatment-waste/che:explosives
sub:site-military;eve:treatment-waste/che:hydrocarbons
sub:site-military;eve:treatment-waste/che:multi
sub:site-military;eve:treatment-waste/che:nerve gas
sub:site-military;eve:treatment-waste/che:nitroaromatics
sub:site-military;eve:treatment-waste/che:organic
sub:site-military;eve:treatment-waste/che:toxins
sub:site-military;eve:treatment-waste/che:v agents
sub:site-military;eve:treatment-waste/nuc:radiation
sub:site-military;eve:weapons-military/che:toxins
sub:site-military;eve:weapons-testing/bio:anthrax
sub:site-military;weapons-military/nuc:radiation
sub:site-miltary;eve:personnel-treatment/che:toxins
sub:site-miltary;eve:treatment-waste/che:g agents
sub:site-miltary;eve:treatment-waste/che:nerve gas
sub:site-miltary;eve:weapons-military/che:nerve gas
sub:site-mining;eve:purif-water/che:iron
sub:site-nuclear;eve:accident-explosion/nuc:radiation
sub:site-nuclear;eve:accident-release/nuc:radiation
sub:site-nuclear;eve:accident-spill/nuc:radiation
sub:site-nuclear;eve:cleaning-metal/nuc:radiation
sub:site-nuclear;eve:protection-personnel/nuc:radiation
sub:site-nuclear;eve:treatment-metal/nuc:radiation
sub:site-nuclear;eve:treatment-waste/che:methane
sub:site-nuclear;eve:treatment-waste/nuc:radiation
sub:site-offshore;eve:accident-spill/che:oil
sub:site-storage tank;eve:accident-spill/che:hydrocarbons
sub:site-storage tank;eve:seepage-storage tanks/che:petroleum
sub:site-storage tank;eve:seepage-strorage tank/che:aromatic hydrocar
sub:site-storage tank;eve:treatment-waste/che:multi
sub:site-storage terminal;eve:accident-leak/che:toxins
sub:site-storage terminal;eve:accident-seepage/che:petrochem
sub:site-storage terminal;eve:seepage-storage tank/che:herbicides
sub:site-storage terminal;eve:seepage-storage tank/che:multi
sub:site-storage terminal;eve:seepage-storage tanks/che:petrochem
sub:site-storage terminal;eve:transport-loading/che:hydrocarbons
sub:site-storage terminal;eve:transport-loading/che:multi
sub:site-transportation;eve:safety-loading/che:multi
sub:site-transportation;eve:safety-storage/che:multi
sub:storage tank-external;eve:accident-spill/che:multi
sub:storage tank-external;eve:treatment-waste/che:multi
sub:storage tank-general;eve:treatment-waste/che:hydrocarbons
sub:storage tank-internal;eve:cleaning-storage tank/nuc:radiation
sub:storage tank-internal;eve:regulatory-chemical/che:toxins
sub:storage tank-internal;eve:treatment-storage tank/nuc:radiation
sub:soil-material;eve:treatment-waste/che:ddt
sub:tubes-internal;eve:metal-corrosion/nuc:radiation
sub:water-ground;eve:accident-seepage/nuc:radiation
sub:water-ground;eve:accident-spill/che:multi
sub:water-ground;eve:accident-spill/che:oil
sub:water-ground;eve:accident-spill/che:toxins
sub:water-ground;eve:purif-water/bio:microbes
sub:water-ground;eve:purif-water/bio:pathogens
sub:water-ground;eve:purif-water/che:aromatic hydrocarbons
sub:water-ground;eve:purif-water/che:biphenyls
sub:water-ground;eve:purif-water/che:heavy metals
sub:water-ground;eve:purif-water/che:hydrocarbons
sub:water-ground;eve:purif-water/che:inorganic
sub:water-ground;eve:purif-water/che:mercury
sub:water-ground;eve:purif-water/che:nitroaromatics
sub:water-ground;eve:purif-water/che:pcb
sub:water-ground;eve:purif-water/che:pesticides
sub:water-ground;eve:purif-water/che:petrochem
sub:water-ground;eve:purif-water/che:solvents
sub:water-ground;eve:purif-water/che:tce

sub:water-ground;eve:purif-water/che:tetrachloroethylene
sub:water-ground;eve:purif-water/che:toxins
sub:water-ground;eve:purif-water/che:trichloroethylene
sub:water-ground;eve:purif-water/nuc:radiation
sub:water-ground;eve:regulatory-labeling/che:multi
sub:water-ground;eve:regulatory-storage/che:multi
sub:water-ground;eve:seepage-storage tank/che:petrochemicals
sub:water-ground;eve:seepage-storage tanks/che:multi
sub:water-ground;eve:treatment-seepage/che:multi
sub:water-ground;eve:treatment-storage/che:multi
sub:water-ground;purif-water/che-toxins
sub:water-sewer;eve:accident-spill/che:petrochemicals
sub:water-waste;eve:accident-leak/che:multi
sub:water-waste;eve:accident-spill/nuc:radiation
sub:water-waste;eve:accident-storage tank/nuc:radiation
sub:water-waste;eve:cleaning-storage tank/che:toxins
sub:water-waste;eve:cleaning-water plant/che:hydrocarbons
sub:water-waste;eve:cleaning-water plant/che:pesticides
sub:water-waste;eve:cleaning-water plant/che:phenol
sub:water-waste;eve:purif-water/bio-bacteria
sub:water-waste;eve:purif-water/bio:pathogens
sub:water-waste;eve:purif-water/che:acid
sub:water-waste;eve:purif-water/che:ammonia
sub:water-waste;eve:purif-water/che:brine
sub:water-waste;eve:purif-water/che:chlorine
sub:water-waste;eve:purif-water/che:contaminants
sub:water-waste;eve:purif-water/che:copper
sub:water-waste;eve:purif-water/che:heavy metals
sub:water-waste;eve:purif-water/che:herbicides
sub:water-waste;eve:purif-water/che:hydrocarbons
sub:water-waste;eve:purif-water/che:hydrogen sulphide
sub:water-waste;eve:purif-water/che:inorganic
sub:water-waste;eve:purif-water/che:leachate
sub:water-waste;eve:purif-water/che:lead
sub:water-waste;eve:purif-water/che:mercury
sub:water-waste;eve:purif-water/che:metals
sub:water-waste;eve:purif-water/che:multi
sub:water-waste;eve:purif-water/che:nitroaromatic compounds
sub:water-waste;eve:purif-water/che:nitrophenol
sub:water-waste;eve:purif-water/che:organic
sub:water-waste;eve:purif-water/che:pesticides
sub:water-waste;eve:purif-water/che:polyvinyl chloride
sub:water-waste;eve:purif-water/che:pumice stone
sub:water-waste;eve:purif-water/che:solvents
sub:water-waste;eve:purif-water/che:thrichloroethylene
sub:water-waste;eve:purif-water/che:toxins
sub:water-waste;eve:purif-water/che:trichloroethylene
sub:water-waste;eve:purif-water/nuc:radiation
sub:water-waste;eve:sensing-product/nuc:radiation
sub:water-waste;eve:treatment-storage tank/che:toxins
sub:water-waste;eve:treatment-waste/bio:brine
sub:water-waste;eve:treatment-waste/che:pcb
sub:water-waste;eve:treatment-water plant/che:hydrocarbons
sub:water-waste;eve:treatment-water plant/che:pesticides
sub:water-waste;eve:treatment-water plant/che:phenol
sub:weapons-general;eve:cleaning-weapons/che:multi
sub:weapons-military;eve:personnel-protection/bio:pathogens

APPENDIX F: Selective List of Decontamination Suppliers and a List of Industries

This lists companies or organizations identified as suppliers of processes, services, products or equipment for remediation of biological or chemical contamination. The list is not comprehensive. It consists only of those entities identified as such in the original documents analyzed.

COMPANY/ ORGANIZATION	COMPANY/ ORGANIZATION
AIR LIQUIDE	AIR PRODUCTS
AIRCO GASES, CARBON DIOXIDE DIVISION	ALCOA
ALLEGHENY TELEDYNE	ALLIED SIGNAL, INC.
ALTUS BIOLOGICS, INC.	ARGONNE NATIONAL LABORATORY
AT&T LABS	AUGUST MACK ENVIRONMENTAL, INC.
AXIS GENETICS	BABCOCK AND WILCOX COMPANY
BENJAMIN MOORE AND CO.	BIRMINGHAM UNIVERSITY
BRITISH GASBRITISH OXYGEN COMPANY (BOC)	BURLINGTON CHEMICAL COMPANY INC
CARGILL EXCEL	RHONE-POULENC
FRIGOSCANDIA	AMERICAN MEAT INSTITUTETX
A&M UNIV. INSTITUTE OF FOOD SCIENCE AND ENGINEERING	CLEVE REBER GROUP
COBIOREM	COMMODORE APPLIED TECHNOLOGIES INC
COMMODORE ENVIRONMENTAL SERVICES INC.	CONSOLIDATED EDISON COMPANY
DE L INSTITUT PASTEUR	DEFENCE SCIENCE & TECHNOLOGY ORGANISATION (DSTO)
DURMECH ENGINEERING, UK	E.I. DU PONT DE NEMOURS
EA ENGINEERING, SCIENCE, AND TECHNOLOGY,	EBARA CORP.
ECOGAS INC	ELF ATOCHEM
ENGINEERED SUPPORT SYSTEMS INC	ENTROPIC SYSTEMS,
ENVIROGEN	ENVIROGEN INC
TEXAS EASTERN TRANSMISSION CORP	PANHANDLE
EASTERN CORP.	ENVIROGEN, INC.
ENVIRONMENTAL TECHNOLOGY DEVELOPMENT	EPA-SUPERFUND
FEDERAL AGRICULTURAL RESEARCH CENTRE (FAL)	FLUOR DANIEL FERNALD
FLUOR DANIEL HANFORD	FORT DETRICK
FOSTER WHEELER	FOSTER WHEELER ENVIRONMENTAL CORP
GEOSAFE AUSTRALIA	GLAXO WELLCOME
GLOVES IN A BOTTLE INC	GRACE DEARBORN
GUEST CARE, INC., DALLAS, TX (SAMLLER SYSTEMS)	HOKKAIDO NATIONAL INDUSTRIAL RESEARCH INSTITUTE
	HTM
HUGHES AIRCRAFT CO.	LOS ALAMOS NATIONAL LABORATORY
ICI	IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY (INEEL).
IDM	IN-SITU FIXATION INC.
INTERA INC	J.R. SIMPLOT COMPANY
KTI RELUB KINETICS TECHNOLOGY INTERNATIONAL	KYUSHU UNIVERSITY
LAWRENCE LIVERMORE NATIONAL LABORATORY	LEVI STRAUSS & CO
LOCKHEED-MARTIN IDAHO TECHNOLOGIES (LITCO).	LOOKED AND ALPHEUS
LOS ALAMOS NATIONAL LABORATORY	THE FLORIDA INTERNATIONAL UNIVERSITY
UNIVERSITY OF MIAMI	LYNCH MINING
MARTIN IDAHO TECHNOLOGIES	MCWHORTER TECHNOLOGIES(IL)
CYTEC (IL)	POLYMER,INC (WI)
UCB CHEM (GA)	CIBA
MERCK	MICRO AIR VEHICLE (MAV)
MICROBIAL AQUATIC TREATMENT SYSTEMS (MATS)	MIT ENERGY LABORATORY
MITSUBISHI	MOSAIC TECHNOLOGIES
MYCOTECH	NATICK (MA) RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
NEGRETTI AUTOMATION	NEOZYME INTERNATIONAL INC.,SUBSIDIARY OF INTERNATIONAL DALECO CORP.
NKK	NSC ENERGY SERVICES
NUFARM CHEMICAL COMPANY	NV VAM
OXYCHEM	PENTEK
POTOK RESEARCH AND PRODUCTION FIRM (MOSCOW, RUSSIA)	PRECISION COMBUSTION, INC.
PRECISION CONTROL	PUBLIC FIRE & HAZMAT TEAMS
REGENESIS	RHONE-POULENC
ROBOTICS DEVELOPMENT GROUP AT WESTINGHOUSE	SATCON TECHNOLOGY CORP.
SAVANNAH RIVER TECHNOLOGY CENTER	SBP TECHNOLOGIES, INC.
SHERWIN-WILLIAMS	SUB-SURFACE WASTE MANAGEMENT, INC.
SYBRON CHEMICALS	TELEDYNE-COMMODORE
COMMODORE APPLIED TECHNOLOGIES INC.	TEXAS INSTRUMENTS

COMPANY/ ORGANIZATION	COMPANY/ ORGANIZATION
TERRAPURE SYSTEMS	THE POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT
TEXTRON DEFENSE SYSTEMS, EVERETT, MA	TOWER ENVIRONMENTAL, SOUTHEAST SOLUTIONS INC
TIOXIDE, AN ICI SUBSIDIARY (UK)	TROJAN TECHNOLOGIES INC.
TRI-O-CLEAN SYSTEMS, INC., FORT PIERCE,FL	UK APPLIED AND ENVIRONMENTAL MICROBIOLOGY
TULANE-XAVIER CENTER FOR BIOENVIRONMENTAL RESEARCH.	US ARMY
UNIROYAL	US SOYBEAN BOARD AND COOPERATING PROJECT PARTNERS.
US DEPARTMENT OF ENERGY	WESTINGHOUSE
VERTEX PHARMACEUTICALS	WHITE CONSOLIDATED
WESTON	
WORLD ENVIROTECH	

This list contains the industries in which decontamination activities either took place or in which suppliers of remediation are based. The titles are not formally matched to such industrial listings as the Standard Industrial Codes. Rather, they define the homogeneous set of roles or activities associated with the labels assigned.

INDUSTRY/SUPPLIERS	INDUSTRY/SUPPLIERS
AGRICULTURE	AIR HANDLING
ANIMAL WASTE TREATMENT	AUTOMOTIVE ENGINE OIL
BEVERAGE MANUFACTURE	BILOLOGICAL RESEARCH
BIOCHEMICAL RESEARCH	BIOCHEMISTRY
BIOREMEDIATION	BIOSENSORS
CHEMICAL MANUFACTURING	CHEMICAL INDUSTRY
CHEMICAL STOCKPILE DISPOSAL PROGRAM	CHEMICAL AND BIOLOGICAL WEAPONS-RESEARCH
CHEMICAL WEAPONS	CHEMICAL MANUFACTURE
CLEANING, ELECTRONICS	CLOTHING MANUFACTURING
CLOTHING REPAIR - MILITARY	COAL POWERED GENERATION INDUSTRY
COATINGS	COMMERCIAL ADHESIVES
COMMERCIAL WASHING/CLEANING	COMMUNICATIONS
ELECTRICITY IN PETROCHEMICAL INDUSTRIES	ELECTRONICS
ENVIRONMENT	ENVIRONMENTAL SERVICES
ENVIRONMENTAL PROTECTION	FARMING
FOOD PROCESSING	FOOD
FOOD PREPARATION	FUEL REPROCESSING
FUSION/LASER RESEARCH	GASES
PLUMBING INDUSTRIES	GENE THERAPY
GOVERNMENT RESEARCH	HAZARDOUS WASTE TREATMENT
HAZMAT RESPONSE	HAZMAT TRANSPORT
HEALTH CARE	HEATING & AIR CONDITIONING
HYDROCARBON PROCESSING	INDUSTRIAL GASES
INDUSTRIAL CLEANING	INKS
IRRADIATION	MANUFACTURING
METALS	MEATPACKING
MEDICAL RESEARCH	MEDICINE
METAL WORKING	MICROBIOLOGY
MICROSENSORS	MINING
NATURAL GAS PRODUCTION	FOOD SAFETY
VETERINARY SCIENCE & MEDICINE	MEDICAL RESEARCH
NUCLEAR WEAPONS MFG	NUCLEAR TRANSPORTATION
NUCLEAR DECON	NUCLEAR POWER, WASTE TREATMENT.
NUCLEAR POWER, PUBLIC SAFETY	NUCLEAR
NUCLEAR WEAPONS AND NUCLEAR POWER	NUCLEAR WASTE TREATMENT
NUCLEAR WEAPONS	NUCLEAR FUEL
NUCLEAR POWER	NUCLEAR MEDICINE
NUCLEAR ARMAMENTS	NUCLEAR ENERGY
NUCLEAR DECOMMISSIONING	NUCLEAR
ORE SMELTERS	PACKAGING
PAINT, COATINGS AND RESIN MANUFACTURE.	PEST CONTROL
PETROCHEMICALS	PETROLEUM
PETROLEUM EXPLORATION	PHARMACEUTICALS
POLYMER CHEM RESEARCH	POLYMERS
PRESERVATION & PROTECTION	PRINTING
PUBLIC WORKS	PULP & PAPER
READY-MIX CONCRETE INDUSTRY	RECYCLING
REFRIGERATION	RESEARCH
RUBBER	SENSING DEVICES
SENSORS	SHIPPING, PETROLEUM INDUSTRY, WASTE

INDUSTRY/SUPPLIERS	INDUSTRY/SUPPLIERS
	TREATMENT.
STEEL	STERILIZATION
TEXTILES	TIMBER, WOOD PRESERVATION AND MARINE BIOLOGY
TRANSPORTATION	TREATMENT
US ARMY	VETERINARY MEDICINE
WARFARE	WASTE TREATMENT
WASTE MANAGEMENT	WASTE TREATMENT - BIOREMDIATION
WASTE TREATMENT - RADIOACTIVE	WATER PURIFICATION
WATER TREATMENT	WEAPONS REMOVAL
WASTE TREATMENT	

APPENDIX G: List of Acronyms

ADF	Australian Defence Forces
ADROWPU	Advanced Double Pass Reverse Osmosis Water Purification Unit
APG	Aberdeen Proving Ground
APPJ	Atmospheric Pressure Plasma Jet
ASH	Activated solution of hypochlorite
ASH	Acidified sodium hypochlorite
AVD	Advanced vapor degreaser
BD	Bibliographic Database
BDO	Battle dress overgarment
BNOM	Background natural organic matter
BOI	Basis of issue
BPL	Beta-propiolactone
BW	Biological weapons
CARC	Chemical agent resistant coating
CASCAD	Canadian Aqueous System for CB Agent Decontamination
CB	Chemical and biological
CBCS	Chemical biological combat suit
CBDCOM	Chemical and Biological Defense Command
CBIAC	Chemical Warfare/Chemical and Biological Information Analysis Center
CEMS	2-chloroethyl methyl sulfide
CFC	Chlorofluorocarbon
CO_2	Carbon dioxide
CSDP	Chemical Stockpile Disposal Program
CSM	Chemical Surety Material
CTAC	N-cetyl trimethylammonium chloride
CW	Chemical weapons
CW/CBD	Chemical Warfare/Chemical and Biological Defense
CWA	Chemical warfare agent
DAAMS	Depot Area Air Monitoring System
DAM	Decontaminating Agent: Multipurpose
DCONGUN	Decontamination gun
DEC	Digital Equipment Corporation
DEDAS	Decontamination Emulsion Direct Application System
DEM	diethyl malonate
DEMP	S-diethylmethylphosphonothiolate
DEPIM	Diethyl pimelate
DETA	Diethylenetriamine
DFP	Diisopropyl fluorophosphate
DIALOG	The Dialog Corporation
DM	Diethyl malonate
DMMP	dimethyl methylphosphonate
DoD	Department of Defense
DOE	Department of Energy
DPE	Demiltarization Protective Ensemble
DPG	Dugway Proving Ground
DSTO	Defence Science and Technology Organisation
DS2	Decontamination Solution No. 2
DTIC	Defense Technical Information Center
ECASOL	Electrochemical Activated Solution
ECBC	Edgewood Chemical Biological Center
EGME	Ethylene glycol monomethylether

EMPA	Ethyl methylphosphonic acid
EWT	Eco Waste Technologies
GPD	Gallons per day
HAZMAT	Hazardous material
HEPA	High efficiency particulate filter
HLB	Hydrophile-lipophile balance
HTH	High Test Hypochlorite
HVAC	Heating, ventilation and air conditioning
HVS	High volume sprayer
ICU	Intensive care unit
ISC	Institute for Surface Chemistry
JSMG	Joint Service Materiel Group
KOH	Potassium hydroxide
LDS	Liquid decontaminant soap
LiOH	Lithium hydroxide
MCBD	Multipurpose chemical, biological decontaminant
MDS	Modular decontamination system
MEA	Monoethanolamine
MeS	Methyl salicylate
NaOH	Sodium hydroxide
NATO	North Atlantic Treaty Organization
NBC	Nuclear, biological and chemical
NPIPP	P-nitrophenyl isopropylphenylphosphinate
NRL	Naval Research Laboratory
NSWC	Naval Surface Warfare Center
NW	Nuclear weapons
OAUGDP	One Atmospheric Uniform Glow Discharge Plasma
OR	Operating room
PAH	Polyaromatic hydrocarbons
PCB	Polychlorinated biphenyls
PGME	Propylene glycol monomethylether
PMCD	Program Manager for Chemical Demilitarization
PNP	Polyethylene glycol
PNPDPP	P-nitrophenyl diphenyl phosphate
PSI	Per square inch
R&D	Research and development
RDT&E	Research, Development, Test and Evaluation
RF	Radio frequency
RFAS	Russian Federation and Associated States
RIER	Reactive ion exchange resins
RO	Reverse osmosis
ROWPU	Reverse Osmosis Water Purification Unit
RSD	Reactive skin decontamination
RSDL	Reactive skin decontaminant lotion
SADS	Surface-Active Displacement Solutions
$SCCO_2$	Supercritical carbon dioxide
SCWO	Supercritical Water Oxidation
SDK	Skin decontamination kit
SET	Solvate electron technology
SME	Subject matter expert
STB	Super Tropical Bleach

STILAS	Scientific and Technical Information Library Automation System
SVOC	Semi Volatile Organic Compounds
TCE	Trichloroethylene
TDG	Thiodiglycol
TDM	Thickened diethyl malonate
TDMA	Thickened dimethyl adipate
TDS	Thickened diethyl sebacate
TECOM	Test and Evaluation Command
TIM	Toxic industrial material
TNT	Trinitrotoluene
TR	Technical Report
TTEP	Thickened triethylphosphate
USAEC	U.S. Army Environmental Center
USAF	U.S. Air Force
UT	University of Texas
UV	Ultraviolet
VAO	vanillyl-alcohol oxidase
VOC	Volatile organic compounds
VMDA	Vehicle Mounted Decontamination Apparatus
WDTIC	West Desert Technical Information Center
WMD	Weapons of mass destruction
WPU	Water purification unit