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POLLUTION ABATEMENT MANAGEMENT SYSTEM--CONCEPT DEFINITION.(U)
MAY 78 R D WEBSTER, E D SMITH

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May 1978
Pollution Abatement Management System

POLLUTION ABATEMENT MANAGEMENT SYSTEM—CONCEPT DEFINITION

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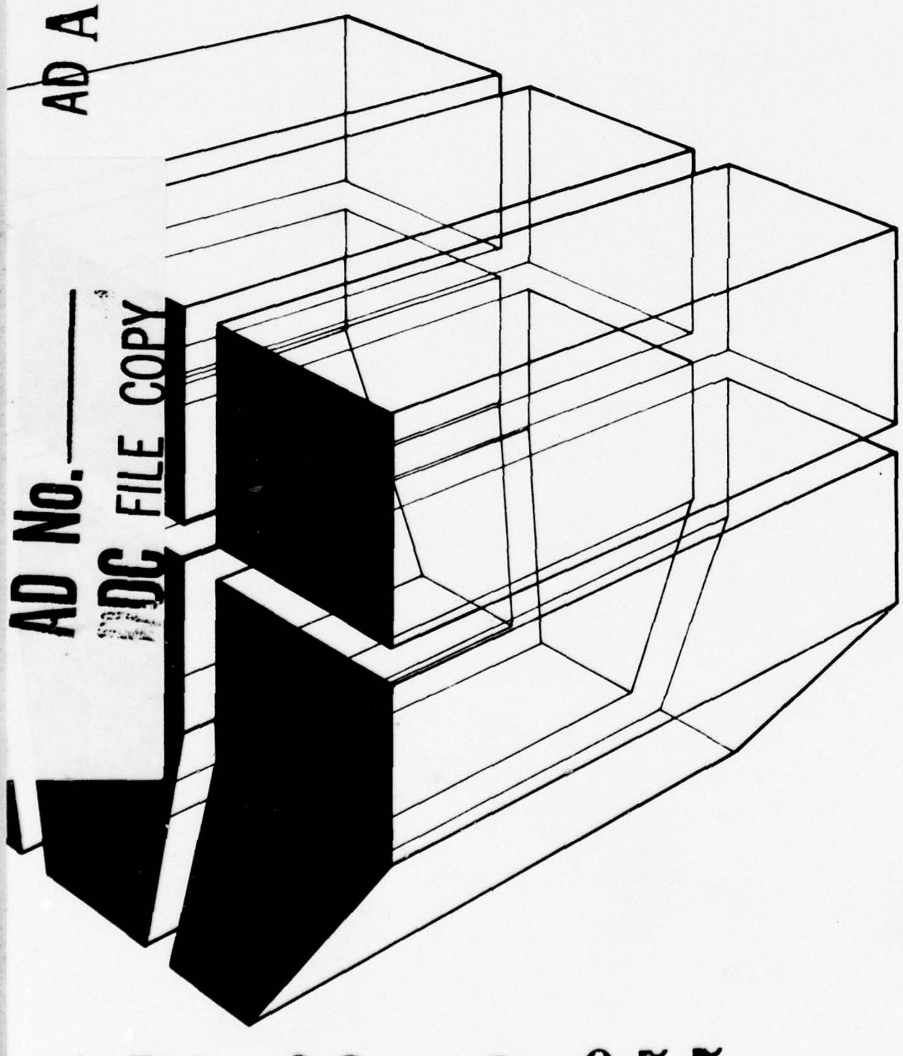

by
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V. Kothandaraman

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Regulatory and legislative requirements of Federal and state pollution control acts such as Public Law 92-500, the Clean Air Act, and the Solid Waste Management Act require Army installations to constrain the effluents of their operations within prescribed limits of quality. The Pollution Abatement Management System (PAMS) will help the facility engineer, Army Major Commands (MACOMs), and headquarters environmental offices implement these requirements by providing manual and computer-assisted procedures to (1) determine the most

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cost-effective, site applicable, energy-conservative solutions for bringing air, water, and solid waste emissions from Army operations into compliance with Federal, state, and Army standards using existing technology and commercial developments wherever possible; (2) monitor the scheduled progress in meeting those prescribed Federal, state, and Army standards; and (3) identify priority ranking of environmental pollution problems within the Department of the Army. This report formalizes the overall concept development of PAMS and the system's developmental strategy.

This strategy provides, in part, that existing pollution problem data and reports routinely provided by Facilities Engineers will be organized into a pollution problems data base. Interfaces with other Army data bases will be established wherever possible. Commercially developed pollution control technology will be classified by media, pollutant process description, and removal efficiency into a technology data base. Technology of interest to the Army will be profiled in advance of the total system's development.

FOREWORD

This study was sponsored by the Directorate of Military Construction, Office of the Chief of Engineers (OCE), under Project 4A762720-A896, "Environmental Quality for Construction and Operation of Military Facilities"; Task T2, "Pollution Control Technology"; Work Unit 008, "Pollution Abatement Management System." The QCR number is 3.01.004.

Mr. V. Gottschalk was the OCE Technical Monitor and Dr. D. Dery was the HQ TRADOC Associate Technical Monitor.

The work was performed by the Environmental Division (EN) of the U. S. Army Construction Engineering Research Laboratory (CERL).

This research was made possible through the efforts of OCE personnel, MACOM advisors, and scientific consultants from the University of Illinois at Urbana-Champaign. Administrative support and counsel were provided by Dr. R. K. Jain, Chief of EN.

COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

TABLES

FIGURES

POLLUTION ABATEMENT MANAGEMENT SYSTEM--CONCEPT DEFINITION

1 INTRODUCTION

Background

The requirements for constraining effluent from Department of Army (DA) installations within prescribed limits are well-documented in such laws as the Federal Water Pollution Control Act (FWPCA),[1] the Clean Air Act,[2] and the Resource Conservation and Recovery Act of 1976.[3] The DA has a peacetime responsibility to *control* pollutants produced by military installations.

As the number of pollutants and the amount of individual discharges grow, the ability of the DA planner and the facility engineer to assimilate and analyze relevant environmental data is decreased. The diversity of regulatory controls, types and frequencies of pollutants, and abatement techniques makes the problem insurmountable using conventional methods.

The Pollution Abatement Management System (PAMS) is a computer-aided system which is being developed to provide the necessary data and analysis tools to the DA planner (at all levels) and the facility engineer to insure informed, effective decision-making regarding abatement strategies and problem analyses.

The *overall* objectives of PAMS are summarized as follows:

1. To develop an inventory of pollution sources at U. S. Army Training and Doctrine Command (TRADOC), Forces Command (FORSCOM), and U. S. Army Material Development and Readiness Command (DARCOM) levels which can be aggregated to Major Commands (MACOMs) and DA levels if necessary.

2. To aid in the periodic monitoring and reporting of scheduled progress in pollution abatement efforts prescribed by Federal, state, and Army standards.

3. To identify priority ranking of environmental pollution problems within DA.

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[1]Public Law 92-500, The Federal Water Pollution Control Act of 1972.
[2]Public Law 91-604, The Clean Air Act 1970 amendments.
[3]Public Law 94-580, The Resource Conservation and Recovery Act of 1976.

4. To develop for the HQ MACOM environmental offices and the facility engineer procedures and data for determining the most cost-effective, site applicable, energy-conservative solutions for bringing air, water, and solid waste emissions from Army operations into compliance with Federal, state, and Army standards, using existing technology and commercial developments where feasible.

5. To identify gaps in technology which may require further research and development.

Purpose

The purpose of this report is to describe the initial development of an overall concept for PAMS, considering both regulatory requirements and user needs.

Approach

The development of PAMS will consist of (1) concept formulation, (2) detailed identification of data sources and user needs, and (3) system development. The study will analyze the variation in pollution abatement problems, available management data, diversity of abatement techniques, and the needs of the DA planner and facility engineer.

The concept formulation was accomplished by dividing the pollution abatement field into three pollutant media subsystems: water, air, and solid waste. User needs were identified, available information was located, and the concept was designed.

Each of the three subsystems will be developed *separately* and aggregation will occur during the final stages of development. This aspect of the PAMS formulation will eliminate the tendency to adhere to a specific software format, a practice which can limit the usefulness of one subsystem while benefiting another. The following chapters will discuss the system's design and framework, data sources, and intended uses by major pollutant category.

Mode of Technology Transfer

The technology transfer will be accomplished in accordance with techniques for computer-assisted systems as defined in appropriate Army regulations.

2 NEEDS OF THE USER

Levels of Need

The requirement of periodic monitoring of pollution abatement and the related new DA guidance have increased the responsibility of environmental personnel at installations, MACOMs, and DA headquarters (HQDA). Although each user has specific needs, a fundamental requirement is uniform among all--the need for better information. The potential users and their related requirements are discussed in the following sections.

The Installation

The installation planner and other installation personnel have two primary responsibilities: (1) sending adequate information regarding pollution problems up the command chain, and (2) requesting abatement assistance from DA to alleviate priority problems. Information generated at the installation through daily logs, self-monitoring reports, emission inventories, etc., is used to coordinate DA policy and management with other government agencies (Office of the Management and Budget [OMB], the U. S. Environmental Protection Agency [USEPA], and other Federal, state, or local agencies). This transfer of information is in the form of established reporting formats and special requests from the MACOMs or HQDA. The effects of these requirements are often the same--the generation of more documentation and reports at the expense of manpower and financial resources.

The Major Command (MACOM)

At the MACOM level, the requirement to forward information up the command chain is the same as the installation level, but is different in form. It often requires consolidating 50 to 100 reports prepared by constituent installations into a summary report. At this level, any lack of uniformity in reporting techniques or interpretations among installations becomes apparent and is often rectified.

The MACOM has the additional responsibility of helping the installation justify and obtain resources and support for abating pollution problems. This requires intimate knowledge of the particular installation's pollution status and the frequency of this type of problem across the entire MACOM. Since this information must often be requested from the installations, it inhibits the entire process.

Headquarters

At the HQDA level, the command chain information flow is still in effect. Some aggregation of the data is performed, but at a lower level of effort because of the smaller number of constituent reporting units. Uniformity can be a problem, but the solution to conflicting formats can often be resolved very quickly.

Since HQDA is the focal point for abatement aid, it requires different types of data and analyses. The efficient funding of abatement construction requires the grouping of projects across installation and MACOM boundaries. In allocating abatement resources, the HQDA planner or manager needs additional information about the frequency and status of pollution problems across the entire Army.

HQDA, acting through the MACOMs and eventually the installations, is responsible for meeting the requirements of appropriate legislative and regulatory agencies at the Federal, State, and local levels. It is essential that the HQDA spokesman have a timely and accurate perception of DA abatement status when dealing with the appropriate agencies.

Current Status

Figure 1 shows the relationship of the various levels of the process. Other Federal or local agencies, such as the EPA or an Air Quality Control Region (AQCR) interact with all levels of the chain. Currently, there is not one level that shares its information sources with another; therefore, the data being used by each can vary due to time differences between reporting requirements, measurement techniques, and individual interpretation. Tracing and comparing relevant information in a decentralized manner without overall systematic design is difficult. As pollution control requirements become more stringent, this problem can become critical.

The increased responsibilities of planning, monitoring, and reporting pollution abatement efforts at DA installations have made the use of computer-aided information storage and retrieval systems indispensable. An interactive, real-time computer storage/retrieval system for pollution abatement management will allow more efficient response to this increased level of responsibility. The real-time system will enable a user to (1) enter into a dialogue with the system, (2) explore the abatement alternatives, and (3) arrive at decisions and obtain required information more expeditiously than is possible with any batch mode or manual system.

The following criteria have been established for the user-oriented aspects of PAMS which are essential ingredients of an "interactive" system.

1. The system must be available almost constantly. The operating software and hardware must be dependable and operable for the

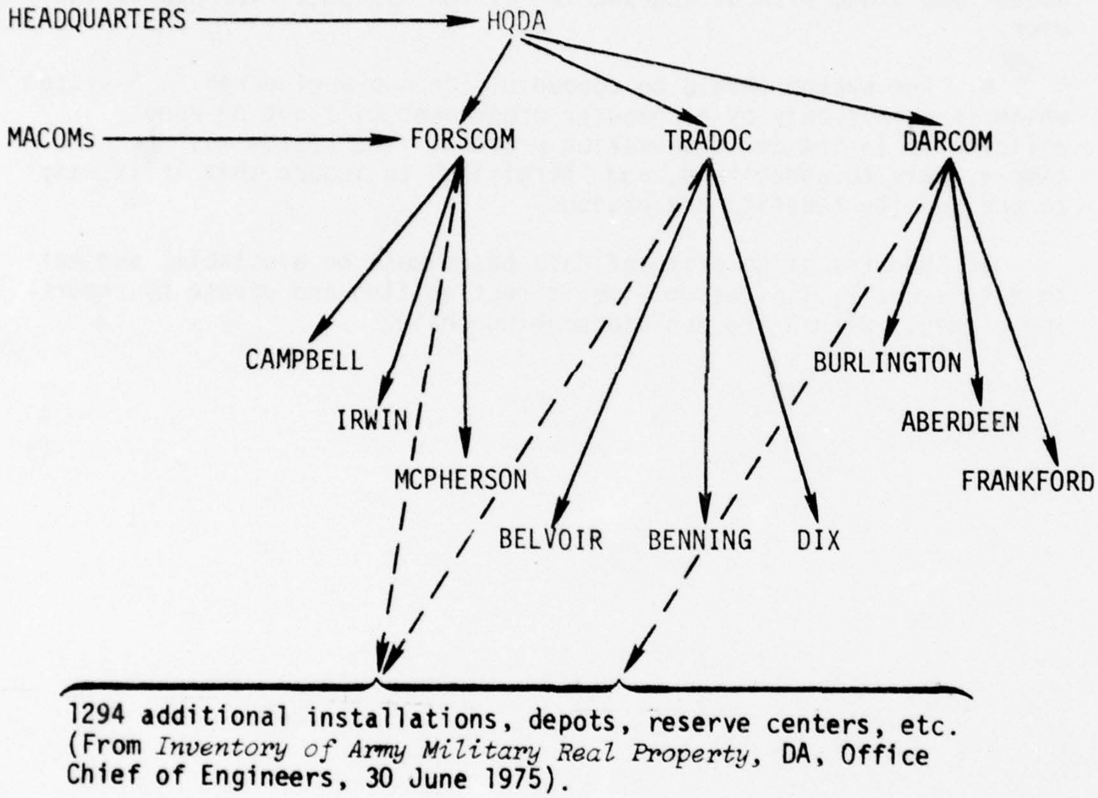

Figure 1. Interaction between command levels.

entire time the system is available, subject to practical limitations. The often "odd hours" of usage dictated by the broad geographic distribution of DA decision makers and the pursuit of critical deadlines should not be viewed as a detriment or special-case usage, since this is precisely the environment in which system value can be established.

2. The system should be designed and documented to be serviced in a very short turnaround time to insure that when inevitable failures occur, their effects are short term.

3. The system should be available to a large number of geographically diverse users. The files should be designed to allow multiple access and usage without degradation of the system's response to the user.

4. The system should be adequately "human-engineered." A system which is usable only by a computer programmer will not be used efficiently in the decision-making process. The system must be simple, easy to understand, and "forgiving" to insure that it is easy to use and its benefits are obvious.

5. Updates of constituent data bases must be available, subject to data security limitations, for direct editing and update by reporting elements within the decision-making chain.

3 THE WATER POLLUTION ABATEMENT SYSTEM (WPAS)

According to DA regulation,[4] major goals of the Army are conserving and protecting water resources from contamination by means of identifying, treating, monitoring, controlling, and disposing of all waterborne wastes produced by Army facilities.

Implementation and enforcement of the applicable Federal or state-developed effluent limitations and water quality standards are accomplished by the regional headquarters of the USEPA through the provisions of the Federal Water Pollution Control Act (Public Law 92-500). These provisions direct that each DA point source of pollution obtain and comply with EPA-issued permits under the National Pollutant Discharge Elimination System (NPDES). Inherent in the Federal Water Pollution Control Act is the objective to restore and maintain the chemical, physical, and biological integrity of the nation's waters.

To implement this law, Congress has required the achievement of specific goals and objectives within a specified time frame. Two overall goals are:[5]

1. To reach, "wherever attainable," a water quality that "provides for the protection and propagation of fish, shellfish, and wildlife" and "for recreation in and on the water" by 1 July 1983.

2. To eliminate the discharge of pollutants into navigable waters by 1985.

To attain these goals, the Act provides for three mitigation achievement phases with accompanying requirements and deadlines.

Phase I, an extension of the programs embodied in many Federal regulations and state laws, requires industry to install "best practicable controls" (BPC); effluents from publicly owned treatment works and other domestic sources must receive the equivalent of secondary treatment by 1 July 1977.

A staff report[6] by the National Commission on Water Quality stated that Phase II requirements are intended to be more rigorous and more innovative. By 1 July 1983, treatment of existing industrial

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[4] *Environmental Protection and Enhancement*, AR 200-1 (DA, December 1975).

[5] *National Commission on Water Quality Staff Draft Report--Issues and Findings* (National Commission on Water Quality, November 1975).

[6] *National Commission on Water Quality Staff Draft Report--Issues and Findings*.

wastewater effluents will employ the "best available technology" (BAT) economically achievable. By 1 July 1983, domestic wastewater limitations will be based on the best practicable waste treatment technology (BPT), including reclaiming and recycling disposal of pollutants. Ultimately, all point-source controls will be directed toward achieving the national goal of eliminating pollutant discharges by 1985.

Army Relevancy

To comply not only with the requirements of the Federal Water Pollution Control Act, but also with its spirit, the Army must contribute to the attainment of the national goal of eliminating the discharge of water pollutants by 1985. Therefore, all point-source domestic and nondomestic effluents from Army installations must ultimately comply with the above limitations.

Table 1 lists the domestic and industrial effluent/pollutants controlled by the provisions of the NPDES permits for Army installations.

It should be apparent that 1983 and 1985 standards will require some form of advanced wastewater treatment, i.e., treatment resulting in nitrate, phosphate, or heavy metal removal; very low values of biochemical/chemical oxygen demand, suspended solids, and fecal coliform bacteria; and minimal fluctuations in temperature and pH. Thus, with the approach of the 1983 target date for employing the best available technology for pollution control and the followup requirement to provide for eliminating the discharge of pollutants by 1985, additional assistance must be provided to installations and construction management agencies responsible for selecting appropriate treatment technology as a mitigation technique for a specific pollution problem.

PAMS is intended to assist decision makers by providing a rapid, up-to-date information system for (1) identifying and ranking DA environmental problems, and (2) evaluating and determining from several alternatives the most appropriate waste treatment process for any Army-related pollution problem. Figure 2 is a flow chart of the Water Pollution Abatement System (WPAS).

The Identification and Ranking of Water Pollution Problems

The basic document in water pollution abatement strategy is the National Pollution Discharge Elimination System (NPDES) permit. Under the NPDES program, it is mandatory that *every* wastewater discharge be authorized by the USEPA (or in certain states, by the state agencies).

Table 1

Industrial and Domestic Point-Source Pollution Effluents Controlled by NPDES Provisions

Parameter	Industrial	Domestic
Biochemical Oxygen Demand $(BOD)_5$	+	+
Suspended Solids	+	+
Fecal Coliforms	+	+
pH	+	+
Total Phosphorus	+	+
Unoxidized Nitrogen	+	+
Total Nitrogen	+	+
Residual Chlorine	+	+
Oil and Grease	+	+
Phenol	+	+
Temperature	+	+
Iron (Dissolved)	+	+
Manganese	+	+
Aluminum (Dissolved)	+	+
Oxygen (Dissolved)	+	+
Chemical Oxygen Demand	+	+
Total Oxidizable Carbon	+	+
Cyanide	+	+
Chromium (total)	+	+
Total Dissolved Solids	+	+
Chromium (Hexavalent)	+	
Lead	+	
Ammonia	+	
Phenol	+	
Sulfate	+	
Chloride	+	
Rise In Temperature	+	
Color	+	
Copper	+	
Cadmium	+	
Mercury	+	
TNT	+	
Nickel	+	
Nitrite	+	
Nitrate	+	
Fluoride	+	
Sodium	+	
Barium	+	
Silver	+	
Total Kjeldahl Nitrogen	+	
RDX	+	
Phosphorus (Ortho)	+	
Specific Conductance	+	
Zinc	+	
Settleable Solids	+	

As such, the NPDES permits for Army installations, under the separate jurisdictions of TRADOC, FORSCOM, and DARCOM, will form the core of the WPAS subsystem. Figure 2 indicates the overall composition of the system and the interrelationship of constituent subprograms.

The NPDES permit for each installation has a unique number, which along with the location of the waste discharges, will be used for identification purposes. Some provisions will be made for identifying point sources which do not fall under the purview of NPDES. This will allow the inclusion of pollution problems which are recognized by environmental offices of MACOMs or installations, but which are not important enough to be included in NPDES.

Each permit stipulates the following criteria:

1. Expiration date of the permit

2. Specific effluent limitations

3. Compliance schedules for meeting effluent limitations

4. Specific sampling and monitoring requirements

5. Specific reporting requirements for documenting permit compliance

6. Special permit conditions.

Figure 3 is a topical listing of the provisions and conditions of the NPDES permit for USEPA Region IV. Preliminary examination of the permits issued by the different regions has revealed a lack of uniformity. Therefore, it will be necessary to store detailed information on monitoring and reporting management requirements, responsibilities, etc., for each of the 10 USEPA regions (Box 2 of Figure 2). However, for each of the Army installations, information on permit number, location, effective date, permit expiration date, details of effluent qualities to be met, schedule of compliance, and schedule of reporting will be stored in the computer file (Box 3 of Figure 2). This will allow access to information on any individual installation, details of special conditions and provisions of the permit, and effluent limitations, schedule of compliance, etc.

One of the important provisions of the NPDES permit is monitoring effluent quality and reporting the results, using EPA form 3320-1. This document will be used to compare waste discharge characteristics against the effluent quality requirements (Boxes 4 and 5 of Figure 2). If there are any violations of the NPDES limitations, the source, permit number, and items in violation will be listed and this information will be retained in computer storage (Box 9 of Figure 2). The

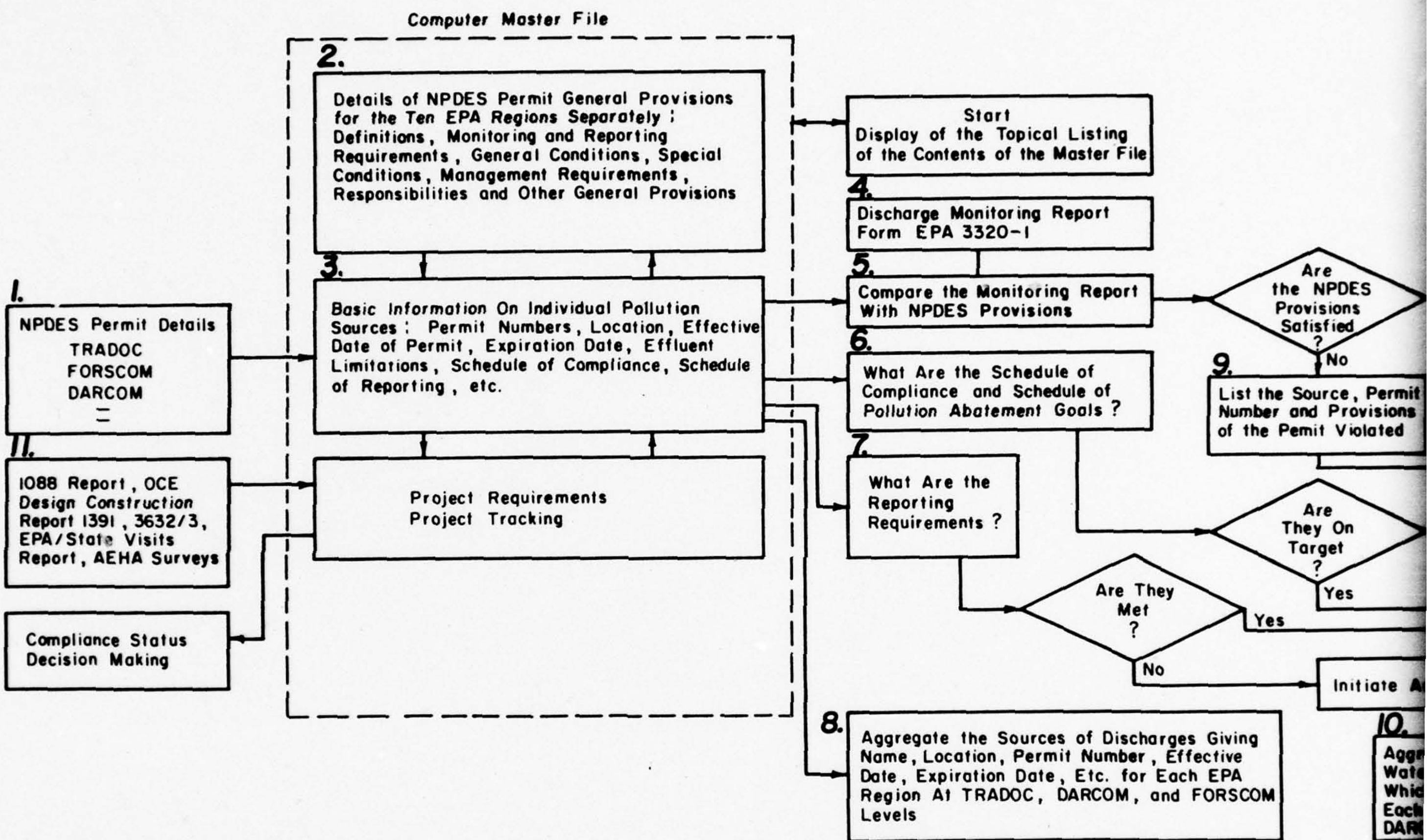
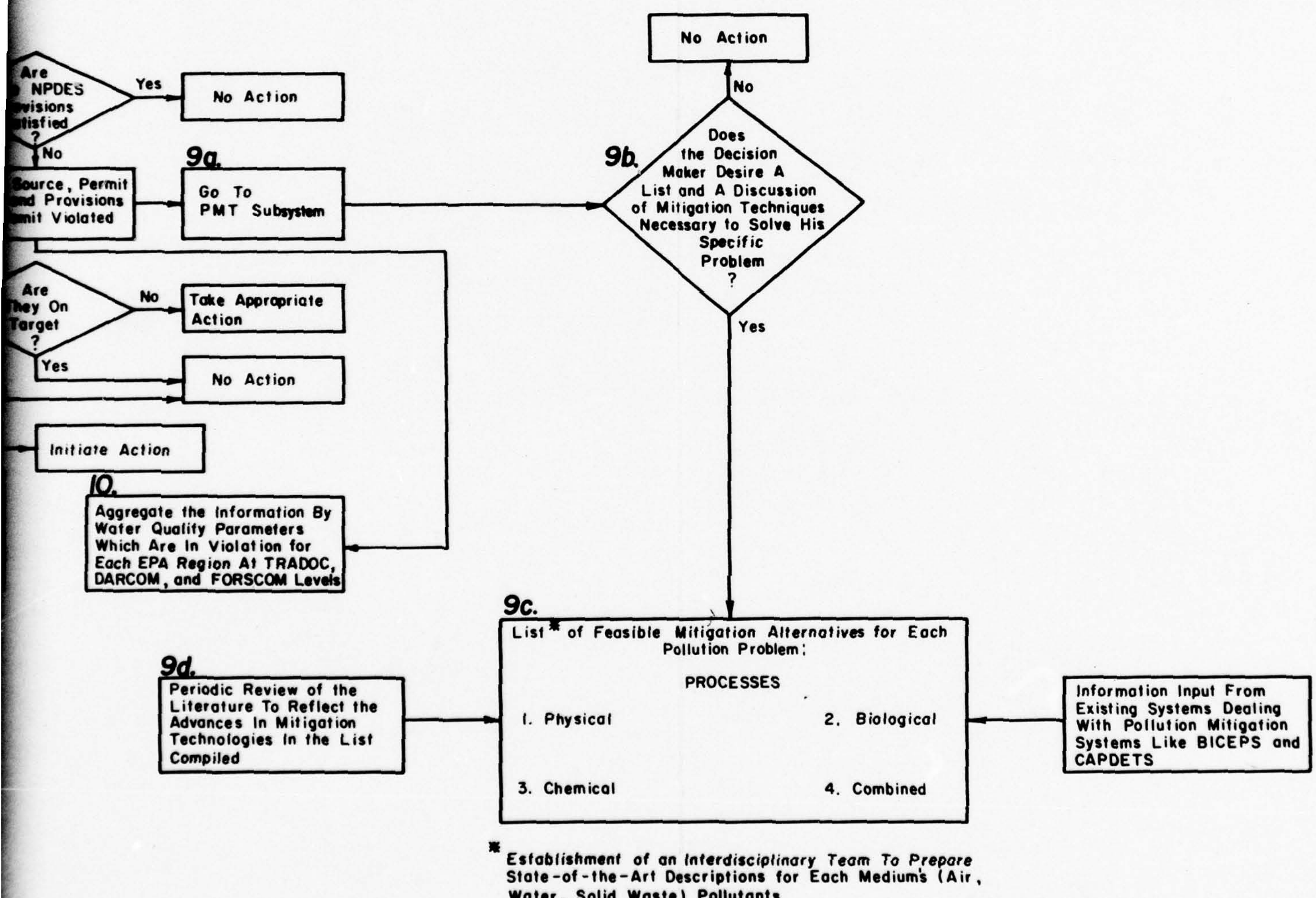


Figure 2. Pollution Abatement Management System--framework for Water Pollution Abatement System (WPAS) components.



No Action
No
Are
NPDES
ovisions
tisfied
?
Yes
No Action
No
9a.
Source, Permit
nd Provisions
mit Violated
Go To
PMT Subsystem
9b.
Does
the Decision
Maker Desire A
List and A Discussion
of Mitigation Techniques
Necessary to Solve His
Specific
Problem
?
Are
hey On
Target
?
No
Take Appropriate
Action
Yes
No Action
Yes
Initiate Action
10.
Aggregate the Information By
Water Quality Parameters
Which Are In Violation for
Each EPA Region At TRADOC,
DARCOM, and FORSCOM Levels
9c.
List * of Feasible Mitigation Alternatives for Each
Pollution Problem;
PROCESSES
1. Physical
2. Biological
3. Chemical
4. Combined
9d.
Periodic Review of the
Literature To Reflect the
Advances In Mitigation
Technologies In the List
Compiled
Information Input From
Existing Systems Dealing
With Pollution Mitigation
Systems Like BICEPS and
CAPDETS
* Establishment of an Interdisciplinary Team To Prepare
State-of-the-Art Descriptions for Each Medium's (Air,
Water, Solid Waste) Pollutants

2

NAME OF PERMITTEE:
APPLICATION NUMBER:
PERMIT NUMBER:
EFFECTIVE DATE OF PERMIT:
EXPIRATION DATE OF PERMIT:
PERMIT ISSUED BY:
LOCATION OF DISCHARGE:
NAME OF RECEIVING WATER:
CLASSIFICATION OF RECEIVING WATER:

PART I

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1. PERIOD OF AUTHORIZATION FOR DISCHARGE
2. EFFLUENT LIMITATIONS
3. SAMPLING POINT, TYPE, AND FREQUENCY
4. EFFLUENT-INFLUENT QUALITIES RELATIONSHIP TO BE SATISFIED

B. SCHEDULE OF COMPLIANCE

C. MONITORING AND REPORTING

1. REPRESENTATIVE SAMPLING
2. REPORTING
3. TEST PROCEDURES
4. RECORDING RESULTS
5. ADDITIONAL MONITORING BY PERMITTEE
6. RECORDS RETENTION
7. LOCATION OF SAMPLING POINT
8. FLOW DETERMINATION
9. SUBSTITUTION FOR BOD TESTS

PART II

A. MANAGEMENT REQUIREMENTS (WHEN THE FOLLOWING OCCUR)

1. CHANGE IN DISCHARGE
2. NONCOMPLIANCE
3. FACILITIES OPERATION
4. ADVERSE IMPACT
5. BYPASSING
6. REMOVED SUBSTANCES
7. POWER FAILURE

Figure 3. An example topical listing of an NPDES permit--Region IV.

B. RESPONSIBILITIES

1. RIGHT OF ENTRY
2. TRANSFER OF OWNERSHIP OR CONTROL
3. AVAILABILITY OF REPORTS
4. PERMIT NOTIFICATION
5. TOXIC POLLUTANTS
6. CIVIC AND CRIMINAL LIABILITY
7. OIL AND HAZARDOUS SUBSTANCE LIABILITY
8. STATE LAWS
9. PROPERTY RIGHTS
10. SEVERABILITY

PART III

A. DEFINITIONS

1. DISCHARGE LIMITATIONS AND MONITORING REQUIREMENTS

A. FLOW
B. CONCENTRATION AND ANY VALUE OTHER THAN FECAL COLIFORM BACTERIA, FLOW, OR LOADING
C. FECAL COLIFORM
D. LOADING
E. OTHER DEFINITIONS

2. DISCHARGE SOURCES

A. POTABLE AND INDUSTRIAL WATER TREATMENT FACILITIES
B. COOLING SYSTEMS
C. BOILERS
D. VEHICLE AND EQUIPMENT CLEANING FACILITIES
E. PAINTING AND CORROSION CONTROL FACILITIES
F. PETROLEUM STORAGE AND HANDLING AREAS
G. VEHICLE AND EQUIPMENT MAINTENANCE FACILITIES
H. BATTERY REWORK FACILITIES
I. PHOTOGRAPHIC LABORATORIES
J. FIRE-FIGHTER TRAINING AREAS

Figure 3 (con't)

B. ADDITIONAL PERMITTED DISCHARGE

1. APPLICABILITY
2. GENERAL CONDITIONS
3. INTERIM DISCHARGE LIMITATIONS AND MONITORING REQUIREMENTS
4. FINAL DISCHARGE LIMITATIONS AND MONITORING REQUIREMENTS

    A. GENERAL REQUIREMENTS
    B. SPECIAL CONDITIONS

        (1) DISCHARGE LESS THAN 2000 GPD
        (2) DISCHARGES TO STORM SEWERS

    C. DISCHARGE LIMITATIONS AND MONITORING REQUIREMENTS

        (1) **POTABLE AND INDUSTRIAL WATER TREATMENT FACILITIES INCLUDING FILTERS, SOFTENERS, AND DEMINERALIZERS**
        (2) **COOLING WATER, COOLING TOWER BLOWDOWN, AND CLEANING WASTES**
        (3) BOILER BLOWDOWN
        (4) VEHICLE EQUIPMENT CLEANING FACILITIES
        (5) PAINTING AND CORROSION CONTROL FACILITIES
        (6) VEHICLE AND EQUIPMENT MAINTENANCE AND STORAGE
        (7) PETROLEUM, OIL, AND LUBRICANT (POL) STORAGE HANDLING AREAS
        (8) BATTERY MAINTENANCE
        (9) PHOTOGRAPHIC LABORATORIES
        (10) FIRE-FIGHTER TRAINING AREAS
        (11) SWIMMING POOLS
        (12) STORM SEWERS

5. **SCHEDULE OF COMPLIANCE**
6. **REQUIREMENTS FOR ADJUDICATORY HEARING REQUEST.**

Figure 3 (con't)

stored information could then be aggregated, giving location, permit number, items in violation, etc., for each EPA region at TRADOC, DARCOM, and FORSCOM levels (Box 8 of Figure 2). The information would also be aggregated by water-quality parameters which are in violation for each EPA region at the MACOM level (Box 10 of Figure 2). This information would be used to (1) identify the problem areas in pollution abatement efforts and to identify priority ranking of environmental pollution problems within DA, and (2) to initiate action to achieve compliance in individual cases.

With access to installation-specific information regarding compliance and pollution abatement schedules, and the comparative status of installations' progress on scheduled projects, it would be possible to keep track of DA performance in meeting pollution abatement goals and objectives. Appropriate action could be initiated when an apparent noncompliance is identified (Box 6 of Figure 2). In addition, reporting requirements can be monitored by using PAMS (Box 7 of Figure 2).

Information on pollution abatement projects from the time of conception, funding, design, and initiation of construction until time of completion would be stored in computer files. The progress of these projects could be monitored by using Office of the Chief of Engineers (OCE) reports 1391, 3632, 3633, reports on EPA/state agency visits, and AEHA surveys (Box 11 of Figure 2). Such a scheme would aid in project tracking and supplement the decision-making process.

The Identification of Alternative Solutions

General Description of the Pollution Mitigation Technique Subsystem

The Pollution Mitigation Technique Subsystem (PMTS) of PAMS will provide a means of identifying and investigating alternative mitigations for identified water pollution problems.

If any violations of the NPDES limitations are noted, the source, permit number, and item in violation will be listed and this information will be retained in computer storage and reported to the proper decision maker (Box 9 of Figure 2). The next step (Box 9a) is initiating action through the PMTS (Box 9b) and subsequently requesting recommended specific pollution mitigation techniques information for an identified problem. The computer will scan the information available in PMTS (Box 9c) and provide a computer printout listing all proven mitigation techniques for the specific pollution problem. Pertinent information will be provided for each alternative in order to provide the decision maker with tools necessary to initiate an appropriate action.

PMTS will provide timely, complete, and reliable information on potential mitigations and will allow access to such information in a straightforward manner. The system output will include all chemical, physical, and biological mitigation processes commonly used to solve specific pollution problems. Each process will be discussed in detail, using a standardized narrative divided into 13 categories.

- Process Name/Definition
- Theory of Process
- Process Description and Characteristics
- Normal Operating Ranges
- Expected Efficiencies
- Cost Considerations
    - Initial
    - Operation and maintenance

Although the control of a specific form of pollutant is the stated objective of PMTS, it is essential that recommended solutions be capable and cost-effective. An expeditious means of accomplishing this objective is to use currently available systems which evaluate cost considerations for waste treatment alternatives. Three such sources of information are readily available, and researchers are investigating coordinating them with PAMS.

The EPA has developed a computer-aided program called Brief Input Cost Estimate Program (BICEP).[7] This system evaluates the relative costs of pollution abatement equipment and labor.

A computer-assisted procedure for designing and evaluating wastewater treatment systems (CAPDET),[8] developed by the U.S. Army Waterways Experiment Station (USAWES), provides guidance for the selection of wastewater treatment trains. The computer-based design procedures can be used to select viable process trains to meet a given effluent criteria and will rank these selected trains according to least cost. Cost and design data are included for 0.3 to 500 million gal/day (mgd)

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[7]Personal Communication of E. Smith (U.S. Army Construction Engineering Research Laboratory [CERL]) with Robert Michael, Facility Requirements Branch, Industrial Construction Division, USEPA, Washington, DC, February 1977.

[8]*Computer-Assisted Procedure for the Design and Evaluation of Wastewater Treatment Systems (CAPDET) User's Guide*, EM 1110-2-174 (Office of the Chief of Engineers, 29 April 1976).

(1.13 to 1890 million ℓ/day) systems. For plants having capacities less than 3.0 mgd, the computer provides information on applicable small-scale facilities. The CAPDET program contains a library of unit processes that may be used to treat a waste stream. This program allows the user to specify various types of unit processes for treating wastewaters. The utility of PMTS is to provide the information necessary to choose which unit process is most applicable for a particular DA waste treatment situation.

The EPA has published a guide[9] for planners, engineers, and decision makers at all levels of government which provides guidance for evaluating the cost effectiveness of alternative wastewater treatment proposals.

- Equipment Considerations

- Advantages/Disadvantages

Currently, there is no "best" solution for pollutant mitigation that is applicable to all situations. Admittedly, certain pollutants may be mitigated by the process commonly used for most applications. However, site-specific characteristics may be better suited to certain uncommonly used mitigation techniques.

- Energy Considerations

Today, energy must be a consideration of all pollution control alternatives. Certain alternatives for water pollution control may save energy, while others may drastically increase total energy use.[10] The overall intent of PAMS requires consideration of the most energy-conservative alternative. The system user must balance the many trade-offs between pollution control and energy consumption, and this aspect of PAMS makes it possible to include energy considerations in the analysis of trade-offs.

- Other Pertinent Information Necessary for Process Evaluation

The following are a few examples of this category:

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[9] *A Guide to the Selection of Cost-Effective Wastewater Treatment Systems*, EPA-430/9-75-002 (USEPA Office of Water Programs Operations, July 1975).

[10] R. M. Hagen and E. B. Roberts, "Energy Requirements for Wastewater Treatment--Part 2," *Water and Sewage Works* (December 1976), pp. 52-57.

Operational safety

Compound selectivity

Interferences

Limitations

Flexibility

Reliability

Process environment

This information helps the decision maker recognize the constraints of each abatement treatment.

- Location of Significant Facilities and Studies

  Domestic

  Industrial

  Army-related

- Manufacturers and Designers

- References

The Appendix provides an example of this type of information for a sample pollutant.

A Preliminary Scheme for the Development of PMTS

Subsystem Objectives. The requirement for increased responsibility (as mandated by NPDES) regarding pollution levels on DA installations has necessitated that MACOM decision makers have an up-to-date, rapid information system concerning available alternative mitigation technology.

Because it is anticipated that pollution control standards will become increasingly stringent, the Army must develop contingency plans for providing retrofit facilities or upgrading existing facilities for treating DA facility domestic and/or industrial wastes. This increased regulation stringency, coupled with high-visibility Army-unique waste streams (e.g., munition plant effluents), necessitates innovative, more effective, off-the-shelf types of advanced treatment.

PMTS is charged with assisting the facility engineer and other decision makers with implementing proper pollution abatement mitigation techniques by providing manual and computer-assisted procedures for evaluating and determining the most appropriate process. The determination will be guided by such principles as identifying the most effective solution (1) having the least initial and maintenance costs, (2) minimizing the consumption of natural material and energy resources, and (3) having the broadest application, while recognizing the great geographical dispersion of these facilities, which vary in size and diversity of activities.

Data Requirements and Source Definition. Development of any information system necessitates that the required data elements and their sources be defined. (The PMTS requires data from the 13 categories defined above.)

The necessary available technology must be collected, completed, and abstracted with the assistance of personnel having expertise in specific waste treatment areas. Therefore, consultation with scientific advisory panels, contractors, and Federal and state agencies must be planned prior to extensive reviews of the literature. After the data from the literature search have been collected and compiled, they must be documented, classified, and abstracted according to the PMTS format.

Next, system software may be developed, which consists of the following tasks:

1. Prepare and load data

2. Verify data loaded

3. Construct retrieval commands

4. Design updating procedures (Box 9d of Figure 2).

4 THE AIR POLLUTION ABATEMENT SYSTEM (APAS)

The Secretary of the Army, acting through the Chief of Engineers, must adopt regulations prescribing policies, responsibilities, and procedures for protecting and preserving the environmental quality at DA facilities. As a result, AR 200-1[11] became effective on 22 December 1975. This regulation provides guidance for implementing pertinent requirements of Federal statutes, regulations, and executive orders[12] pertaining to environmental protection and enhancement. This guidance will be followed by the DA military commands.

The Clean Air Act establishes the legal basis for improving and maintaining air quality to protect public health and welfare. Included in its provisions are the establishment of National Ambient Air Quality Standards to identify (1) the acceptable health and welfare levels which will be permitted for a given pollutant, (2) allowable significant air quality deterioration zones which set the allowable amount of air quality deterioration, and (3) the preparation of Implementation Plans by each state to provide for the attainment of primary standards by 1 July 1975, and secondary standards within a reasonable time.

The stipulations of the Clean Air Act and AR 200-1 apply to (1) each active, semiactive, and Army Reserve installation operated by or for the Department of the Army and National Guard facilities/sites supported by Federally appropriated funds in the Continental United States, (2) Alaska and Hawaii, (3) the Commonwealth of Puerto Rico, (4) the Virgin Islands, (5) Guam, (6) American Samoa, (7) the Panama Canal Zone, and (8) the Trust Territories of the Pacific. These regulations apply whether or not these facilities are Army-controlled or under jurisdiction of the Army by lease or similar instrument.

Reporting Requirements

The DA has several reporting requirements regarding control of environmental air pollution from existing facilities.

[11] *Environmental Protection and Enhancement*, AR 200-1 (DA, December 1975).

[12] Executive Order 11752--*Prevention, Control, and Abatement of Environmental Pollution at Federal Facilities* (38 FR 34793, 19 December 1973); The National Environmental Policy Act of 1969 (42 USC 4321-4347); Public Law 91-604 Clean Air Act, and Clean Air Amendments of 1970 (December 1970).

Part D of AR 200-1 implements the Clean Air Act as amended in 1970, DOD Instruction 4120.14,[13] and Executive Order 11752.[14] According to Subpart J of the regulation, compliance with Federal, state, interstate, and local standards for air emissions and national ambient air quality is required.

More particularly, according to the stipulations outlined in the Clean Air Act:

1. Existing stationary sources (e.g., heating plants) must have reduced emissions to comply with the law by 31 December 1975 or must have negotiated compliance dates with the USEPA.[15]

2. All new stationary sources must be designed and operated to comply with published standards.[16]

3. Nonstationary sources must be designed and operated to comply with published standards.[17]

Common sources of air pollution which must be controlled include:

1. Heating plants having more than 1 million Btu per hour input

2. Incinerators

3. Large electrical-power generating plants

4. Manufacturing processes/acid production facilities

5. Metal cleaning and treatment operations

6. Spray-painting operations

7. Petroleum, oil, and lubricants storage and dispensing facilities.

National Ambient Air Quality Standards[18] prescribe maximum

[13] *Air and Water Pollution Control*, DOD Directive 4120.14 (Department of Defense, May 1971).

[14] *Prevention, Control, and Abatement of Air and Water Pollution at Federal Facilities*, Executive Order 11752 (December 1973).

[15] *USA Training and Doctrine Command Environmental Program Handbook* (TRADOC, 29 March 1977), p. A-3.

[16] *USA Training and Doctrine Command Environmental Program Handbook.*

[17] *USA Training and Doctrine Command Environmental Program Handbook.*

[18] *Environmental Protection and Enhancement*, AR 200-1 (DA, December 1975).

pollutant levels for particulate matter, sulfur oxides, carbon monoxide, photochemical oxidants, hydrocarbons, and nitrogen oxides. In all instances, as reported in AR 200-1, the states have specified (in their USEPA-approved Implementation Plans) strict ambient air quality standards and established maximum levels for each pollutant based on the type of source. The applicable standard must be achieved by each Army facility. Further guidance for specific state regulations can be obtained by using the Computer-Aided Environmental Legislative Data System (CELDS).[19]

AEHA Report

For each stationary source of air pollution reported in the facilities' inventories, the installation Directorates of Facilities Engineering (DFAE) must submit a report to the Army Environmental Hygiene Agency (AEHA). AEHA checks these reports for compliance with the appropriate air pollution control law.

Environmental Pollution Control Report

Each installation which does not meet current standards must complete an Environmental Pollution Control Report (RCS DD-I & L [SA] 1383) which states the facility's proposed plans and funds for projects to remedy the pollution problem.

Air Pollutant Emissions Report (APER)

The USEPA[20] requires that all Army facilities periodically submit air quality data in an Air Pollutant Emissions Report (OMB Form Number 168-R76) in order to provide an inventory of air pollution source emitters.

EPA Compliance Schedule Consent Agreements

The USEPA determines from the APER whether the source has complied with applicable Federal, state, and local substantive standards and regulations and whether there is a requirement for a formal consent agreement. For sources not in compliance for which consent agreements must be negotiated (between the Army and state or municipality with the USEPA's sanction), the source is allowed to continue operating subject to certain conditions, usually embodied in a schedule for

[19] *User Manual for the Computer-Aided Environmental Legislative Data System*, Technical Report E-78/ADA019018 (CERL, November 1975).
[20] *Federal Register*, Vol 40, No 92, "Guidelines for Federal Agencies Compliance with Stationary Sources Air Pollution," 6 May 1975.

actions to be taken by the Army activity to accomplish compliance. Determination of whether a source requires a consent agreement is made on a case-by-case basis, considering such factors as the type of source, its location (whether in a nonattainment air quality control region), technology and alternatives available, and time from compliance according to [illegible]tes listed in the Clean Air Act.

Vapor Recovery Projects

As proposed state transportation air pollution control plans are implemented, vapor control recovery systems at gas stations may be required.[21] This implementation may entail an additional reporting requirement at each facility.

Air Pollution Emergency Episode Plans

Each state is required by Section 110 of the Clean Air Act of 1970 to adopt and submit to the USEPA administrator a scheme which provides for the implementation, maintenance, and enforcement of national ambient air quality standards within each air quality control region that is wholly or partly within that state. Each implementation plan must include a system for curtailing pollutant emissions on an interim basis whenever such action appears to be necessary for preventing short-term episodes of high pollutant concentration.[22]

It is Army policy to participate with local authorities to the fullest extent practicable in controlling air emissions during air pollution emergency episodes. Paragraph 4-17, AR 200-1, requires installations located in areas susceptible to air pollution episodes to develop contingency plans which, when implemented, will reduce emissions. Such plans may involve reducing operation of certain fixed facilities and/or reduction in the use of government vehicles.[23] Air Pollution Emergency Episode Plans must be filed with the appropriate state agency.

The Environmental Office of the Assistant Chief of Engineers requests[24] that the status of the installation contingency plans be included in the installation's annual status report on environmental programs and activities, since no information regarding status of compliance with this requirement is available at headquarters. It is suggested that, as a minimum, the information should include the following:

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[21] *USA Training and Doctrine Command Environmental Program Guidebook* (TRADOC, 29 March 1977), p D-4-1.
[22] *Guide for Air Pollution Episode Avoidance* (USEPA, June 1971).
[23] DAEN-ZCE Message, R0415382, October 1976, Subject: Air Pollution Emergency Episode Plans.
[24] DAEN-ZCE Message R0415382.

1. Whether the installation is located in an air quality control region that is subject to air pollution episodes and that requires preparation of a contingency plan. If not, no further information is required.

2. The number of times the contingency plan was implemented at the emergency level (not the alert or warning level) during the year.

It is anticipated that APAS will provide these reporting requirements.

Miscellaneous Reporting Requirements

If periodic USEPA/state visits and inspections note deficiencies or delays in complying with the stipulations outlined in the USEPA Compliance Schedule Consent Agreement, the plans must be renegotiated and documented.

Despite the above reporting requirements and a July 1975 deadline, as many as 30 percent (as of January 1977) of the major DOD polluting installations were still not complying with the emission control requirement of the Clean Air Act.[25]

According to the General Accounting Office (GAO) report[26] prepared by the Congressional Investigative Agency, some DOD installations may not comply for several more years.

The report therefore recommends that the Army:

1. Evaluate current air pollution emission inventories to isolate violations of stationary source standards

2. Develop the funding programs needed to attain full compliance by whatever new deadline is set

3. Make a thorough investigation, if and when additional standards are issued to identify sources not in compliance, and take the action necessary to meet new standards in a timely manner

4. Establish procedures to isolate "controllable"* causes which delay projects

5. Adopt a system of scheduled surveys and establish procedures for monitoring installations' actions on survey team recommendations.

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[25] *Department of Defense Air Pollution Control: Progress and Delays*, General Accounting Office report LCD-77-305 (GAO, July 1975).
[26] GAO Report LCD-77-305.
*The report categorizes the "controllable" causes as: (1) lengthy decision-making processes on controlling emissions, and (2) prolonged project design phases.

The report emphasizes the fact that the Navy makes regular technical environmental surveys of its installations and requires feedback on recommended actions, but the Army surveys installation problems only on request and does not have a procedure to guarantee that recommendations are carried out.

A Proposed System to Meet Air Pollution Requirements

To aid the Army with the above recommendation in the air pollution area, the following major tasks must be accomplished:

1. A data base must be developed which can define air pollution problems stemming from the operations of Army facilities. This involves entering data from present DA reporting media into a workable retrieval system. Currently, collecting data regarding reporting requirements of compliance schedules and monitoring of scheduled success requires laborious handwork. This is primarily because data from overlapping reporting requirements and a myriad of different sources makes it difficult for one command to efficiently maintain the status of all pollution sources. Thus, the aforementioned reporting requirements will constitute the basic documents for monitoring DA air pollution control efforts.

2. A data base must be developed which is capable of identifying alternative mitigation techniques for air pollution abatement strategies for the DA planner. A format similar to that of the PMTS system (Chapter 3) will be adopted.

Figure 4 outlines the general flow of APAS.

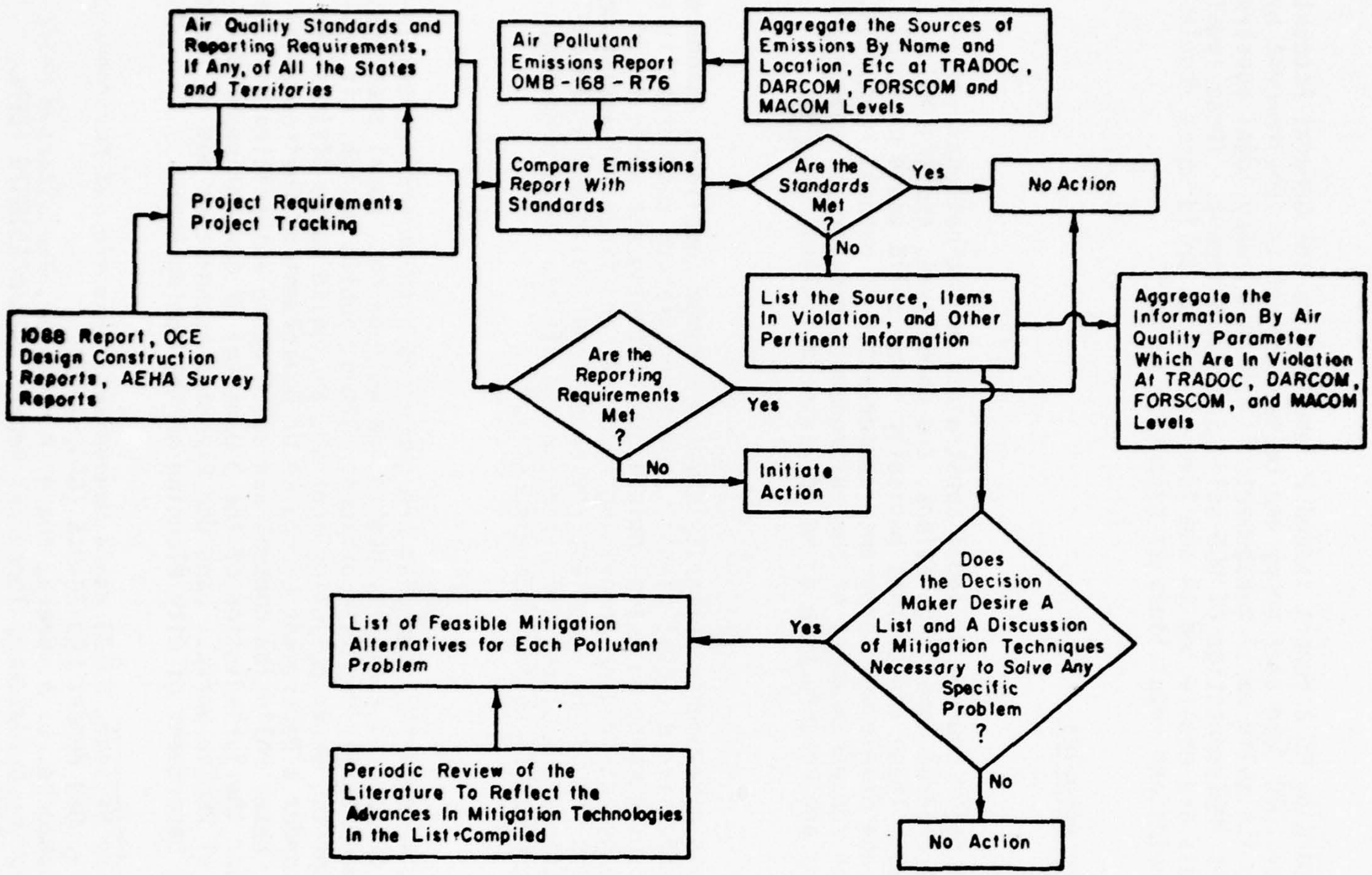

Figure 4. Framework for Air Pollutant Abatement System (APAS) components.

5 THE SOLID WASTE POLLUTION ABATEMENT SYSTEM (SWPAS)

According to a report issued 2 June 1977 by the General Accounting Office, DOD "can save money and better protect the environment by improving its solid waste management."[27] However, many legal constraints affect the implementation of DOD solid waste management. These legal constraints are manifested in the form of various solid waste regulatory agencies and regulations as discussed below.[28]

Regulatory Agencies

Federal

The major sources of legal constraints on the national level include (1) Federal laws, regulations, and guidelines, and (2) DOD directives. These constraints basically cover solid waste disposal, research and development programs, conservation of natural resources, protection and enhancement of the environment, recovery of energy and materials, and construction of solid waste facilities.

State

State governments primarily develop minimum compliance standards and comprehensive disposal plans. Typical regulatory responsibilities of state solid waste agencies include administering the state solid waste management program, providing technical and financial assistance for various regulating agencies, reviewing local solid waste management practices and plans, and acting as the official governing body for all aspects of solid waste disposition.

Local

Local regulatory agencies are concerned with enforcing legislation and protecting community health and well-being. Local agencies are not necessarily separate offices. Often, public health, air pollution control, water pollution control, and solid waste offices are combined under a Department of Health or Department of Environmental Quality. Water Pollution control and solid waste authorities are sometimes under the jurisdiction of the Department of Sanitation or Department of Public Works. Land Use Planning Authorities may be found under the Department of City Planning or the Zoning Board.

[27] *Improving Military Solid Waste Management, Economic and Environmental Benefits*, GAO report LCD-76-345 (GAO, 1977).
[28] G. W. Schanche, L. A. Greep, and B. A. Donahue, *Installation Solid Waste Survey Guidelines*, Technical Report E-75/ADA018879 (CERL, October 1975).

Federal Laws and Regulations

Laws

1. The Solid Waste Disposal Act of 1965[29] promotes material research and development programs for solid waste disposal and conservation of natural resources. In addition, it provides technical and financial assistance to state and local governments and interstate agencies. The USEPA administrator who enforces this act must promote coordination of research and development, and must encourage, cooperate with, and render financial and other assistance to appropriate public authorities, agencies, institutions, and individuals.

2. The National Environmental Policy Act (NEPA)[30] establishes a national policy regarding the restoration, protection, and maintenance of all aspects of environmental quality.

3. The Resource Recovery Act of 1965,[31] amends the Solid Waste Disposal Act to provide money for building solid waste disposal facilities and for improving training and research programs. This Act includes Title I, "Resource Recovery," which is charged in part with:

a. Promoting the demonstration, construction, and application of solid waste management and resource recovery systems that preserve and enhance the quality of air, water, and land resources

b. Promoting research and development for improved management techniques, more effective organizational arrangements, and new and improved methods of collection, separation, recovery, recycling, and disposal of nonrecoverable residues.

Executive Orders

1. Executive Order 11514, Protection and Enhancement of Environmental Quality (5 March 1970), states, in part, that the heads of Federal agencies will:

a. Monitor, evaluate, and control their agencies' activities for protection and enhancement of environmental quality

b. Disseminate information for public review and exchange views with interested parties through public hearings

c. Review statutory authority, administration regulations, policies, and procedures in order to identify deficiencies or

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[29]Public Law 89-272, The Solid Waste Disposal Act (20 October 1965).
[30]Public Law 91-190, The National Environmental Policy Act (NEPA) (1 January 1969).
[31]Public Law 512, The Resource Recovery Act (26 October 1970).

inconsistencies which prohibit or limit full compliance with the purposes and provisions of NEPA

d. Exchange environmental data with other governmental agencies.

This order establishes the responsibilities of the Council on Environmental Quality.

2. Executive Order 11574 (23 December 1970), provides for the administration of the Refuse Act Permit Program and extends the purposes and policies of Section 13 of the River and Harbors Act of 3 March 1899;[32] the Federal Water Pollution Control Act, as amended; the Fish and Wildlife Coordination Act, as amended;[33] and NEPA.

The Executive Branch uses the permit program to regulate discharge of pollutants and other refuse into navigable waters of the United States and their tributaries, and to regulate placement of the refuse on their banks. The Secretary of the Army administers this order, and the Attorney General is present at legal proceedings.

Guidelines

The USEPA's Title 40, *Protection of the Environment*, Part 240--"Guidelines for the Thermal Processing of Solid Wastes," and Part 241--"Guidelines for the Land Disposal of Solid Wastes," present guidelines for designing and operating landfills and incinerators. This authority stems from the Solid Waste Disposal Act of 1965, and the Resource Recovery Act of 1970.

Part 240 presents guidelines for designing and operating incinerators which process at least 2.08 tons/hour (TPH) (1.87 t) or 50 tons/day (TPD) (4.5 t). It provides guidelines for accepting and rejecting solid wastes, selecting incinerator sites, designing incinerators, maintaining air and water quality, controlling vector populations, maintaining the aesthetics of the surrounding area, disposing of incinerator residues, operating the incinerator, keeping records, and maintaining worker safety.

Part 241 covers landfills and includes guidelines for accepting or rejecting solid wastes, selecting a landfill site, designing a landfill, maintaining air and water quality, controlling gas production and vector population, operating the landfill, maintaining safety, and keeping records.

[32]River and Harbors Act of 3 March 1899, c. 425, 30 Stat. 1152 (33 U.S.C. 407).
[33]Fish and Wildlife Coordination Act, as amended (16 U.S.C. 661-666c).

Other guidelines include:

1. Guidelines for Beverage Containers (*Federal Register*, 21 September 1976, Vol 41, No. 184).

2. Guidelines for Resource Recovery on Facilities (*Federal Register*, 24 September 1976, Vol 41, No. 184).

3. Solid Waste Management Guidelines for Source Separation (*Federal Register*, 23 April 1976, Vol 41, No. 80).

4. Guidelines for Storage and Collection of Residential, Commercial, and Institutional Solid Waste (*Federal Register*, 13 February 1976, Vol 41, No. 31).

DOD Policy

DOD Directive 6050.1, *Environmental Considerations in DOD Actions*, establishes the Department's policy, assigns responsibilities, and guides the implementation of Section 102(2) of NEPA, the Armed Forces Appropriation of 1970,[34] sections of the Clean Air Act, as amended, and various executive orders dealing with environmental quality. This directive, which applies to the whole Department, dictates the policy to which DOD agencies must adhere and assigns responsibilities to the officers of those agencies.

Army Policy

1. AR 420-47, *Repairs and Utilities--Refuse Collection and Disposal*, prescribes sound sanitary engineering procedures for efficiently and economically collecting and disposing of refuse. It applies to all installations and activities within the purview of AR 420-10.[35]

2. AR 200-1, *Environmental Quality--Environmental Protection and Enhancement* (7 December 1973), supersedes paragraphs 1-1 through 1-6 AR 11-21, *Army Programs: Environmental Pollution Abatement* (3 November 1967), implements DOD Directive 5100-50, and provides general Department of the Army policy on environmental protection. The regulation applies to all DA agencies except the civil works functions of the Corps of Engineers.

Paragraph 1-8 requires that annual status reports on environmental programs, accomplishments, and problem areas be filed. For solid waste management, the report must include a summary of waste disposal operations and waste recovery (property disposal activities and recycling operations).

[34]Public Law 91-121, Armed Forces Appropriation of 1970.
[35]*Facilities Engineering--General Provisions*, AR 240-10 (DA, October 1973).

State Solid Waste Regulating Agencies

The regulatory responsibilities of most state solid waste agencies are very similar and generally include power to:

1. Administer the state solid waste management program pursuant to the laws of the state.

2. Provide technical assistance to municipalities, agencies, and individuals, and cooperate with appropriate Federal agencies and private organizations in controlling solid wastes.

3. Promote the planning and application of resource recovery systems that preserve and enhance the quality of air, water, and land resources.

4. Serve as the official state representative for all purposes of the Federal Solid Waste Disposal Act, as subsequently amended, and for all other state or Federal legislation regarding the management of solid waste.

5. Review solid waste management plans for each municipality or region.

6. Develop, in cooperation with appropriate state agencies and other interested parties, a program for the collection, storage, and disposal of abandoned vehicles.

7. Prepare and enforce regulations governing solid waste storage, collection, transport, separation, processing, and disposal in order to conserve the air, water, and land resources of the state; protect the public health; prevent environmental pollution and public nuisances; and enable implementation of the purposes and provisions adopted in the state solid waste management plan.

8. Establish procedures for applying for, reviewing, and issuing permits that govern the design and operation of solid waste management facilities and systems.

9. Enforce orders, after investigation or hearing, on all violations of state regulations.

10. Cooperate with appropriate Federal authorities to secure compliance with applicable Federal statutes, orders, and guidelines for solid waste management activities conducted by Federal agencies within the state.

Army Responsibility--The Resource Conservation and Recovery Act of 1976

The new Federal solid waste management legislation, the Resource Conservation and Recovery Act of 1976, was passed by the 94th Congress and signed into law by the President on 21 October 1976. It amends and expands provisions of the Solid Waste Disposal Act of 1965, which was amended by the Resource Recovery Act of 1970. According to Section 6001, the provisions of the Resource Conservation and Recovery Act of 1976 apply to each Federal agency.

With regard to the Army, the most significant aspect of the new Act is that Federal, state, interstate, and local substantive and procedural (administrative) requirements for controlling and abating solid waste or hazardous waste disposal are fully applicable. Applicable requirements include any stipulations for permits or reporting or any provisions for injunctive relief and associated sanctions.

Implementation

The USEPA will administer the Solid Waste Disposal Act through its Office of Solid Waste. Regulations for management of hazardous waste and guidelines for state and regional solid waste schemes must be promulgated no later than 21 March 1978; however, enforcement is not likely until some time in 1979.[36]

Definitions

According to the Navy Environmental Support Office, it is apparent "that the common meanings of such terms as disposal, sanitary landfill, open dump, solid waste, and sludge have now been expanded by legal definition. As an example, sludge now includes waste from an air pollution control facility. Hazardous waste and other terms related to hazardous waste management are newly defined. Hazardous waste is considered to be that *solid waste* which has specific hazardous attributes. On the other hand, the definition of solid waste neither specifically includes nor excludes hazardous waste. It would appear that the term solid waste is intended to include hazardous waste unless the context in which the term is used implies otherwise."[37]

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[36] *Information Bulletin*, 11ND-CBC-5215/4 (Naval Construction Battalion Center, July 1975).

[37] *Navy Environmental Support Office Information Bulletin* (Department of the Navy, 28 March 1977).

Monitoring and Records

Monitoring

Under the provisions of paragraphs 1 to 8, AR200-1, all Army installations must monitor their operations to the extent necessary to insure that no solid waste activity is a source of environmental degradation.

DOD will also monitor all solid waste activities with sufficient frequency to insure continued compliance with the provisions of AR 420-47.

Records

AR 420-47 requires that DA Form 3916 (Daily Log of Truck Trips of Solid Waste and Salvage Collection) and DA Form 3917 (Solid Waste and Salvage Collection) be used to record data on solid waste collection, disposal, source separation, and resource recovery at installations and activities. Entries on DA Form 3916 will be made daily by solid waste collection truck drivers. These data will be consolidated monthly on DA Form 3917 by solid waste collection supervisors. Quantities reported on DA Form 3917 should be recorded in units of uncompacted cubic yards as outlined in the DA technical manual (TM) 5-634 *Refuse Collection and Disposal; Repairs and Utilities* (2 July 1958). Data from this form will be used to prepare the applicable portions of the DA Form 2788 series (Technical Data Report).

Reports

AR 420-47 requires the Managing Activity to complete an Annual Report of Solid Waste Source Separation and Resource Recovery/Recycling Operations (RCS-DD I&L[A]-1436). The report will be forwarded to the MACOMs for consolidation prior to submission to HQDA (DAEN-FEU) WASH DC 20314. MACOM reports will be forwarded to reach DAEN-FEU no later than 15 November of the following fiscal year. Replacement equipment acquisition financed by net proceeds of sales (from AMS Code 728012.27000) will describe each item of equipment, the number of units procured, and the total cost of procurement.

Reports of compliance/noncompliance with the USEPA guidelines on solid waste management will be consolidated by DAEN-FEU. Feeder reports from all Army installations will be reported annually. Specific guidance will be provided by DAEN-FEU when USEPA's reporting form and instructions are published.

Function of the Solid Waste Pollution Abatement System

SWPAS is charged with a multifaceted software task:

1. Assisting each facility and command with the solid waste related reporting requirements described above.

2. Developing a solid waste information service for the DA which provides an inventory of all disposal sites, including the location, capacity, remaining volume, types and quantities of waste materials, and cost of operation.

3. Developing a responsive technology and information transfer service (similar to the Navy system[38]) pertaining to the collection, handling, reuse, and disposal of solid and hazardous wastes.

[38] *Navy Environmental Support Office Bulletin* (Department of the Navy, 28 March 1977).

6 CONCLUSIONS

This report has provided an overall concept definition for the Pollution Abatement Management System which will be developed for use by DA planners (planners and decision makers at different levels) and facility engineers to assist Army installations in constraining the effluents of their operations within prescribed limits of quality. The needs of the user and the availability of different data were identified by working with the MACOMs and the facility engineers. The concept definition has taken into account the regulatory requirements in areas of water, air, and solid waste management.

PAMS will be divided into three subsystems: water, air, and solid waste. The water-related subsystem will be developed first using existing Army-specific pollutant data and establishing the necessary mitigation and abatement data base system for the identification of solutions. The air and solid waste subsystems will follow. Subsequent aggregation of these subsystems will result in an overall system which will (1) determine the most cost-effective, site applicable, energy-conservative solutions for bringing air, water, and solid waste emissions from Army operations into compliance with Federal, state, and Army standards using existing technology and commercial developments wherever possible; (2) monitor the scheduled progress in meeting those prescribed Federal, state, and Army standards; and (3) identify priority ranking of environmental pollution problems within DA.

APPENDIX:

A PRELIMINARY EXAMPLE OF POLLUTION MITIGATION TECHNIQUE SUBSYSTEM (PMTS) DATA

Assume that a particular DA wastewater treatment facility experiences repeated violations of the nitrate provisions stipulated in the NPDES permits. Once the facility decision maker concludes that a retrofit process should be added to existing facilities, he/she enters PMTS via an interactive, in-house terminal. Using the keyword "nitrate," he/she types a request to the computer for the desired information. The computer then provides a printout with a complete descriptive discussion of each of the following mitigation techniques.

1. Biological denitrification
2. Ion exchange
3. Bacterial and algal assimilation
4. Distillation
5. Land application
6. Freezing
7. Electrodialysis
8. Reverse osmosis
9. Ultrafiltration
10. Chemical denitrification

This appendix presents a typical narrative description of the biological denitrification mitigation technique. When the system is fully operational, the decision maker will be able to obtain pertinent information concerning each mitigation technique.

<u>Biological Denitrification: Definition</u>

Biological denitrification is an anaerobic process in which nitrogen gas is produced from nitrite and/or nitrate. The heterotrophic bacteria which participate in this process include pseudomonades, achromobacters, and bacilli. Denitrification is generally considered to be a tertiary or advanced retrofit-type wastewater treatment process which follows secondary and nitrification facility treatments. Denitrification has been tested and operated under a variety of conditions and has consistently and reliably achieved a high removal of nitrogen at an acceptable cost.

Characteristics of Denitrified Water[39]

Denitrified water is not dark and odorous as are some anaerobic waters because denitrification is not a typical anaerobic reaction. Instead, it is similar to aerobic oxidations, with nitrates as the final electron acceptor. Unless excessive organic carbon is present, odiferous products such as idol, skatol, and hydrogen sulfide are not produced. Thus, the organic dosage must be controlled carefully.

If methanol is used as the electron donor, the residual methanol concentration will probably be too low to be of public health significance. Perhaps the most detrimental effect of the residual methanol is its oxygen-consuming potential.

Other constituents in denitrified water must also be considered. The treated water may contain some nitrate, nitrite, and ammonia nitrogen, as well as some turbidity resulting from biological solids in the effluent of the final clarifier. In addition, the water will be devoid of oxygen. Table A1 shows the typical expected effluent quality from denitrification facilities.[40]

In the United States, where nitrogen removal criteria have been adopted by many states, the most popular and common nitrogen removal scheme, according to the USEPA, is *biological denitrification* preceded by nitrification.[41]

Theory

The nitrogen in raw municipal wastewater is primarily present in the ammonia-ammonium and inorganic forms.

In the United States and Canada, most domestic sewage treatment plants use biological treatment as part of the organic removal process. This biological treatment for organic removal causes organic nitrogen to be converted to ammonia. However, if denitrification is to provide a significant nitrogen reduction, then essentially all of

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[39] P. P. St. Amant and P. L. McCarty, "Treatment of High Nitrate Waters," *Journal of American Water Works Association* (December 1969), pp 659-662.

[40] *Nitrification and Denitrification Facilities--Wastewater Treatment* (USEPA, August 1973).

[41] *Process Design Manual for Nitrogen Control* (USEPA, October 1975).

Table A1

Expected Typical Effluent Quality From Denitrification Facilities

Component	Milligrams per Liter
Suspended solids	10
BOD	5
Organic-N	1.0
NH_4-N	.5
NO_3-N	.5
Total-N	2.0

this ammonia nitrogen in the raw wastewater must be converted to nitrate and/or nitrite prior to the denitrification step. The biological oxidation process used for this conversion is called nitrification. Thus, denitrification facilities usually are preceded by secondary sewage treatment plants and nitrification facilities.

The biological process of denitrification applies to the removal of nitrogen from wastewater when the nitrogen is predominantly in the nitrite and/or nitrate forms. This nitrate and/or nitrite is converted to gaseous end products during denitrification, which reduces the nitrogen content of the wastewater as it escapes from solution and is released to the atmosphere. The gaseous product is primarily nitrogen gas. Since approximately 80 percent by volume of the earth's atmosphere consists of nitrogen gas, the small amount added to the atmosphere by denitrification facilities may be considered negligible. Since this process places the nitrogen removed from wastewater back into the ecosystem as elemental nitrogen (the most stable and natural state) it is truly a pollution control process and not a separation process that transfers the problem to another geophysical location.[42]

The microbiology and biochemistry of denitrification is generally well known. A relatively broad range of bacteria can accomplish

[42]M. Sittig, *Pollutant Removal Handbook* (Noyes Data Corp., 1973) p 321.

denitrification, including *Pseudomonas, Achromobacter, Bacillus,* and *Micrococcus.*[43] These groups accomplish denitrification by nitrate dissimilation, whereby nitrate or nitrite replaces oxygen in the respiratory processes of the organism under anaerobic conditions. During denitrification or nitrate reduction, these organisms also require an organic source of carbon for energy and growth. Since most of the available organic carbon has already been oxidized in a typical nitrification plant effluent, an external source of organic carbon such as methanol must be added to the reactor basin to insure successful denitrification.

A flash aeration chamber located between the anaerobic denitrification reactor and the final settling tank occludes the nitrogen gas from the treated wastewater, enhances settleability, reaerates the water, and volatilizes most of the residual ammonia.

Process Description and Characteristics

Denitrification facilities have been designed and constructed using either complete-mix reactors or static media filters with plug-flow regimes. Although numerous variations and modifications of these two types of denitrification processes exist, most facilities use either of these two general methods. Both methods require an anaerobic environment in the denitrification reactor.

The following paragraphs describe the characteristics of complete-mix and static-media denitrification.

Complete-Mix Denitrification

This denitrification system, the one used most extensively, consists of a complete-mix denitrification tank followed by a clarifier for sludge removal. This system is also called suspended growth denitrification. The system consists of a basin with underwater mixers comparable to those used in water-works flocculation tanks. The energy gradient must be sufficient to keep the microbial flow in suspension but controlled enough to prevent aeration, unless the reactor is covered to reduce contact with air.[44]

Suspended growth reactors typically have the problem of maintaining a large, viable suspended culture in the biological system.

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[43] *Pollutant Removal Handbook.*

[44] *Proceedings of Professional Conference on Nitrogen in the Environment,* compiled by R. A. Wiese and P. D. Axthelm (18-19 April 1973).

This involves problems of liquid solids separation, recycle, and "wasting of cells."[45] To assist in mitigating these problems, a capability of returning sludge to the denitrification tank of up to at least 50 percent and preferably of up to 100 percent of average flow is recommended.[46]

Provisions similar to those employed for carbonaceous systems should also be made for periodic wasting of sludge from the denitrification systems. Normally, the sludge should be wasted to mix with primary and/or waste-activated sludge and be disposed of with them.[47]

Static-Media or Fixed-Film Denitrification

In contrast to complete-mix reactors, attached-biota or static-media reactors hold the microbiological population of denitrifying bacteria as a slime to the media surface, thus eliminating the need for solids wasting and recycling. This form of denitrification facility is characterized by the influent passing through a column of media such as rock or sand. In addition to these media, a variety of matrix materials on which denitrifying bacteria can proliferate have been investigated and have proven successful.[48] The use of small particles such as sand provides a vast surface area on which the bacteria may grow and thereby remarkably increases the amounts of contaminant that can be removed in a given volume of reactor.[49]

Fixed-film denitrification has the added benefit of filtration, and under normal circumstances, will produce an effluent low in suspended solids concentration.[50] One researcher[51] states that the columnar fixed-film reactor appears more efficient than the suspended-growth type reactor and holds promise for a wider application.

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[45] J. S. Jeris and R. W. Owens, "Pilot Scale High Rate Denitrification," *Journal of Water Pollution Control Federation,* Vol 47, No. 8 (August 1975), pp 2043-2057.

[46] *Nitrification and Denitrification Facilities--Wastewater Treatment* (USEPA, August 1973).

[47] *Nitrification and Denitrification Facilities--Wastewater Treatment.*

[48] Metcalf and Eddy, Inc., *Wastewater Engineering--Collection, Treatment, and Disposal* (McGraw-Hill, 1972).

[49] J. S. Jeris and R. W. Owens.

[50] *Nitrogen Control* (USEPA).

[51] M. Sittig, *Pollutant Removal Handbook* (Noyes Data Corp., 1973), p 322.

Normal Operating Ranges

Empirical analyses of the operational range of denitrification facilities for the treatment of domestic wastewater indicate that the nitrate and nitrite-nitrogen concentration of the system influent is usually between 15 and 40 mg/ℓ.

Numerous industrial wastewaters characterized by much higher nitrate-nitrogen concentrations also use biological denitrification facilities for nitrogen control.

Expected Efficiencies

An important consideration when evaluating any treatment system is the degree of nitrogen removal. Because denitrification technology is relatively new, some design engineers are concerned that biological nitrification-denitrification systems are unstable and produce highly variable results. However, large-scale tests of biological nitrogen removal via denitrification have demonstrated that a consistently low nitrogen level can be obtained over relatively long periods of time.[52]

Since only oxidized forms of nitrogen (nitrite and/or nitrate) are removed by denitrification, denitrification facilities are generally preceded by secondary sewage treatment and nitrification. Consequently, the efficiency of most denitrification facilities is evaluated in conjunction with this pretreatment. The efficiency of the process is thus dependent on the efficiency of the nitrification process.

Based on available data, the general consensus is that denitrification systems are capable of consistently high levels of nitrogen removal. In fact, denitrification preceded by secondary biological treatment and nitrification should achieve 80 to 95 percent total nitrogen removal at design flows.[53]

Table A2 compares the effect on nitrogen compounds of various treatment processes and denitrification.

Table A3 compares the residuals in liquid effluents from various types of 100 mgd treatment plants.

Cost Considerations

Generally, denitrification processes preceded by secondary treatment and nitrification facilities have been empirically found to be an

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[52] *Process Design Manual for Nitrogen Control* (USEPA, October 1975).
[53] M. J. Hammer, *Water and Wastewater Technology* (John Wiley and Sons, Inc., 1975), p 458.

Table A2

Effect of Various Treatment Processes on Nitrogen Compounds (From *Process Design Manual for Nitrogen Control* [USEPA, October 1975])

Treatment process	Effect on constituent: Organic N	NH_3/NH_4^+	NO_3^-	Removal of total nitrogen entering process, percent[a]
Conventional treatment processes				
Primary	10-20% removed	no effect	no effect	5-10
Secondary	15-25% removed[b] urea → NH_3/NH_4^+	10% removed	nil	10-20
Advanced wastewater treatment processes				
Filtration[c]	30-95% removed	nil	nil	20-40
Carbon sorption	30-50% removed	nil	nil	10-20
Electrodialysis	100% of suspend organic N removed	40% removed	40% removed	35-45
Reverse osmosis	100% of suspend organic N removed	85% removed	85% removed	80-90
Chemical coagulation[c]	50-70% removed	nil	nil	20-30
Land application				
Irrigation	→ NH_3/NH_4^+	→ NO_3^- → plant N	→ plant N	40-90
Infiltration/percolation	→ NH_3/NH_4^+	→ NO_3^-	→ N_2	0-50
Major nitrogen removal processes				
Nitrification	limited effect	→ NO_3^-	no effect	5-10
Denitrification	no effect	no effect	80-98% removed	70-95
Breakpoint chlorination	uncertain	90-100% removed	no effect	80-95
Selective ion exchange for ammonium	some removal, uncertain	90-97% removed	no effect	80-95
Ammonia stripping	no effect	60-95% removed	no effect	50-90
Other nitrogen removal processes				
Selective ion exchange for nitrate	nil	nil	75-90% removed	70-90
Oxidation ponds	partial transformation to NH_3/NH_4^+	partial removal by stripping	partial removal by nitrification--denitrification	20-90
Algae stripping	partial transformation to NH_3/NH_4^+	→ cells	→ cells	50-80
Bacterial assimilation	no effect	40-70% removed	limited effect	30-70

[a] Will depend on the fraction of influent nitrogen for which the process is effective, which may depend on other processes in the treatment plant.

[b] Soluble organic nitrogen, in the form of urea and amino acids, is substantially reduced by secondary treatment.

[c] May be used to remove particulate organic carbon in plants where ammonia or nitrate are removed by other processes.

Table A3

Residuals in Liquid Effluent From 100 mgd* Treatment Plants (From R. M. Hagen and E. B. Roberta, "Energy Requirements for Wastewater Treatment--Part 2," *Water and Sewage Works*, Vol 123, No. 11 [December 1976], pp 52-57.)

Residuals (lb/day)	Activated Sludge	Alum Treatment with Nitrification/ Denitrification	Coagulation/ Filtration with Zeolite Treatment	Land Treatment
BOD	8,000-30,000	6,700	840	170-500
Suspended solids	8,000-30,000	5,930	250	580-1,670
P	8,400	250	840	83
N	21,000	1,680	420-840	3,200
Heavy metals	250-5,000	2,000-3,000	negligible	20-320

economically feasible method for removing nitrogen from wastewater in large-scale water reclamation projects.

Carlson reports that Wuhrmann, one of the most active researchers and writers on the subject of microbiological denitrification, compared various pollution control programs and concluded that the least expensive nitrate control can be obtained with microbial denitrification.[54]

However, costs associated with biological denitrification systems are specific to each situation and time frame, and generalizations are therefore difficult to make. Long-run operating costs are of interest, but the long-term prices of chemicals and energy are particularly difficult to estimate.[55] In addition, experience with full-scale denitrification units is relatively limited. Consequently, the following discussion of costs is indicative only of general trends and must be viewed with caution in specific cases.

* Metric conversion: 1 gal = 3.78 *l*.

[54] D. A. Carlson, *Nitrogen Removal and Identification for Water Quality Control* (National Technical Information Service Pamphlet, August 1971), p 7.

[55] *Process Design Manual for Nitrogen Control* (USEPA, October 1975), p 9-4.

Cost ranges for biological denitrification facilities (excluding pretreatment and post treatment) are situation specific. Therefore, it is difficult to report specific cost figures which apply to all denitrification regimes. It is especially difficult to accurately report dollar values for capital costs and for operating and maintenance costs per million gallons per day that are applicable to all situations.

Although detailed investigations must be performed to determine the exact costs of denitrification facilities, Figure A1 compares the costs of such facilities to conventional treatment alone and to conventional treatment coupled with nitrification facilities. The figure incorporates the approximate national average total costs, including plant amortization (25 years at 6 percent), operation, and maintenance.

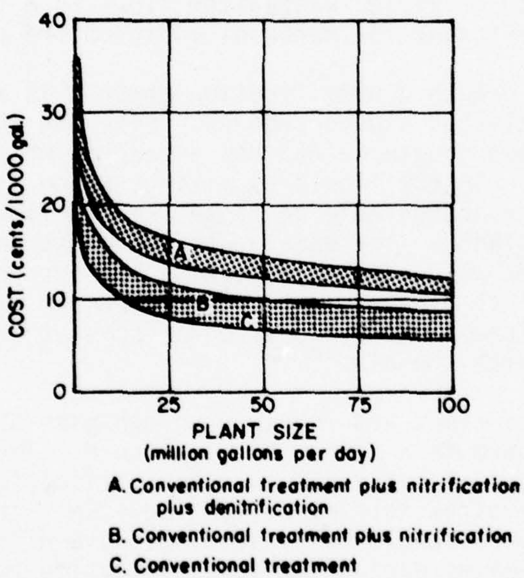

Figure A1. Cost considerations.
(From *Nitrogen Control* [USEPA]).

The major cost of the denitrification process (approximately 50 percent) is for methanol. Currently, there is disagreement about the future costs of methanol. Newer technology for methanol production indicates that costs may be reduced; however, a major method of methanol production is based on the use of methane gas, whose source is natural gas, a nonrenewable resource which is becoming scarce. The cost of the denitrification reactor and attendant equipment depends on the type of reactor chosen, land value, and other considerations.

Construction costs for static-medium denitrification filters are significantly less than those for a suspended-growth reactor, since the latter must be followed by a clarification step and attendant sludge return equipment. Another advantage of using a static-medium denitrification filter to remove suspended solids is that it is less expensive. At low liquid temperatures (<10°C), biological nitrification-denitrification becomes less cost effective, because tankage requirements become very large.[56]

Equipment Considerations

Suspended Growth Reactors

In this method, nitrified wastewater flows to a tank where methanol is added, so provisions for methanol addition are required.

The suspended growth denitrification process is an anaerobic modification of the activated sludge process. Like the activated sludge process, the suspended growth method has a reactor which keeps the biomass in suspension in the liquid by mixing, which is accomplished with underwater mixers comparable to those used in flocculation tanks in water-treatment plants. The energy provided must be sufficient to keep the mixed liquor suspended solids (MLSS) in suspension, but must be controlled enough to prevent entry of atmospheric oxygen as much as possible, unless the tanks are covered or some other method is used to exclude contact with the air.[57]

Whether covered tanks are required to minimize absorption of oxygen from the atmosphere is a matter of conjecture. There is some evidence to indicate that properly designed denitrification units can be made to seal themselves by forming a floating scum. In any event, airtight or walk-in covers should be avoided, because nitrogen and carbon dioxide are both released during the denitrification reaction.[58]

The denitrification reaction produces carbon dioxide and nitrogen gas. Both have limited solubility in water, especially the latter. Because of the gentle mixing used in the denitrification tanks, the mixed liquor leaving the tanks is supersaturated with nitrogen, and

[56] *Process Design Manual for Nitrogen Control* (USEPA, October 1975), p 9-4.

[57] *Nitrification and Denitrification Facilities--Wastewater Treatment* (USEPA, August 1973), p. 32.

[58] *Nitrification and Denitrification Facilities--Wastewater Treatment,* p 27.

possibly carbon dioxide. As a result, gas bubbles tend to form, which adhere to the MLSS and inhibit settling in the final clarifier. Supersaturated conditions can be relieved by employing an aeration tank or by using aerated open tanks prior to the settling tank. It is recommended that 5 to 10 minutes of detention be provided at peak flow. This will also enable the removal of small amounts of excess methanol.

A sedimentation tank for separating the mixed liquor solids from the effluent must be provided. This tank allows the biomass to be recycled in the system and allows the production of a relatively clear effluent for discharge or subsequent treatment.

Limited experience indicates that the settling properties of denitrification sludge, following relief of supersaturation, are very similar to conventional activated sludge. Tank depths of 12 to 15 ft (3.6 to 4.5 m) are recommended.

A suction-type sludge collector is recommended for large circular tanks. Long rectangular tanks should be equipped with midtank sludge-drawoff systems. Skimming facilities should be provided on the settling tanks and provisions made for returning the scum to the denitrification tank.[59]

Static-Media or Fixed-Film Reactors

The basic design of a fixed-film reactor is a column filled with filtering media. Backwashing equipment may be necessary. Generally sedimentation basins following the column reactor are not needed. As in suspended growth denitrification, provisions must be made for adding methanol or any other carbon source. The treated effluent should be aerated before discharge.

Advantages of the Denitrification Process

Of the biological treatment methods proposed for removing nitrogen, the denitrification process preceded by nitrification appears to be the most promising.[60]

Generally, denitrification is considered very applicable for nitrate removal because of its relatively excellent reliability and suitability to a variety of environmental conditions, low area requirements, moderate cost, easy process control, and high-potential nitrogen removal efficiency. Several other advantages are listed below.

[59] *Nitrification and Denitrification Facilities--Wastewater Treatment*, EPA Technology Transfer Seminar Publication (USEPA, August 1973), p 27.

[60] Metcalf and Eddy, Inc., *Wastewater Engineering--Collection, Treatment, and Disposal* (McGraw-Hill, 1972), p 662.

1. Denitrification preceded by secondary biological treatment and nitrification facilities should achieve 90 percent inorganic nitrogen reduction and 80 to 85 percent total nitrogen removal at design loadings.[61]

2. The most desirable nitrogen removal process is one by which nitrogen is transformed with no waste stream disposal. The reduction of nitrate and nitrite-nitrogen gas meets these requirements. Thus, denitrification has the advantage of returning nitrogen to the atmosphere in its natural, ecologically harmless form.[62]

3. Denitrification preceded by nitrification leads to a net reduction in wastewater alkalinity and no significant change in the water's total mineral content.[63]

4. Very little liquid or solid waste by-products are created in the process.[64]

5. Process structures and equipment are relatively simple.[65]

6. Denitrification systems are adaptable as retrofit additions at existing nitrification facilities.

7. The denitrification system can be built to meet current and anticipated requirements for nitrate removal.

8. Denitrifying bacteria are easily domesticated.

9. Biological denitrification is relatively independent of the ambient temperature and can be operated over a wide temperature range. Compared to other nitrogen removal processes, biological denitrification is better suited at locations where cold, freezing weather may prevail for a long period of time.[66]

10. The process is compatible with phosphorus removal.

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[61] *Proceedings of Professional Conference on Nitrogen in the Environment*, 18-19 April 1973, Lincoln, Nebraska, compiled by R. A. Wiese and P. P. Axthelm, p 71.

[62] *Proceedings of Professional Conference on Nitrogen in the Environment*.

[63] *Process Design Manual for Nitrogen Control* (USEPA, October 1975).

[64] R. L. Culp and G. L. Culp, *Advanced Wastewater Treatment* (Van Norstrand Reinhold Co., 1971).

[65] *Advanced Wastewater Treatment*.

[66] M. Sittig, *Pollutant Removal Handbook* (Noyes Data Corp., 1973).

Disadvantages of the Denitrification Process

The following are disadvantages of the denitrification process:

1. Only oxidized forms of nitrogen (nitrate and/or nitrite) are removed by biological denitrification. The efficiency of the process is therefore dependent on the efficiency of the nitrification process.

2. One hundred percent nitrogen removal is not possible.

3. Toxic compounds can affect system stability adversely.

4. Denitrification systems are primarily for the removal of nitrate-nitrogen. The relatively low concentration of nitrite-nitrogen typically present in wastewaters is only removed incidentally. Studies would have to be initiated to determine the feasibility of treating wastewaters containing high concentrations of nitrite.

5. Nitrate nitrogen which might otherwise be recovered for use as fertilizer is lost to the atmosphere in the form of gaseous nitrogen.

Table A4 compares the advantages and disadvantages of various denitrification systems.

Energy Considerations

In some areas, available nitrogen-deficient industrial wastes such as brewery waste might be suitable as an external carbon source for the denitrification process. These wastes should be used when possible instead of methanol, which is produced from a limited resource.

A report reviewing the typical energy requirements for wastewater treatment plants listed the following information:

> The power requirements for nitrification and denitrification in a 100 mgd (381 ℓ) treatment plant are approximately 60,000 and 1000 kWh/day, respectively. Production and transport of the methanol used consumes approximately 36,000 kWh/day, and construction of the additional facilities averages approximately 17,500 kWh/day. Table A5 summarizes these data.

Table A6 compares the total energy requirement for a denitrification system preceded by activated sludge, alum treatment, and nitrification facilities to two other possible nitrogen removal schemes.

Table A4

Comparison of Denitrification Alternatives
(From *Process Design Manual for Nitrogen Control* [USEPA, October 1975] pp 5-62.)

	kWh/day		
	Activated Sludge, Sludge Digestion, Landfill Disposal	Activated Sludge, Alum Treatment, Nitrification/ Denitrification	Activated Sludge, Coagulation/Filtration Lime Recalcination, Activated Carbon Absorption, Zeolite Ion Exchange
Direct energy required	61,462	137,749	616,721
Chemical supply	12,658	58,959	480,702
Construction of facilities	19,162	38,684	39,155
Total	93,282	235,392	1,136,578

Table A5

Energy Required for Nitrification/Denitrification in 100 mgd* Plant (Following Activated Sludge With Alum Treatment)
(From R. M. Hagen and E. B. Roberta, "Energy Requirements for Wastewater Treatment--Part 2," *Water and Sewage Works*, Vol 123, No. 11 [December 1976], pp 52-57.)

	kWh/day
Nitrification	60,259
Denitrification	1,020
Production and transport of methanol	35,826
Construction of facilities	17,538
Total	114,643

(These figures will be affected by site- and application-specific considerations.)

*1 gal = 3.78 ℓ

Table A6

Total Energy Required for Three Different Levels of Wastewater Treatment (100 mgd)
(From R. M. Hagen and E. B. Roberta, "Energy Requirements for Wastewater Treatment--Part 2," *Water and Sewage Works*, Vol 123, No. 11 [December 1976], pp 52-57.)

System Type	Advantages	Disadvantages
Suspended growth using methanol following a nitrification stage	Denitrification rapid, small structures required Demonstrated stability of operation Few limitations in treatment sequence options Excess methanol oxidation step can be easily incorporated Each process in the system can be separately optimized High degree of nitrogen removal possible	Methanol required Stability of operation linked to clarifier for biomass return Greater number of unit processes required for nitrification-denitrification than in combined systems
Attached growth (column) using methanol following a nitrification stage	Denitrification rapid, small structures required Demonstrated stability of operation Stability not linked to clarifier as organisms on media Few limitations in treatment sequence options High degree of nitrogen removal possible Each process in the system can be separately optimized	Methanol required Excess methanol oxidation process not easily incorporated Greater number of unit processes required for nitrification-denitrification than in combined system

Power requirements (for the mixers in a suspended-growth type reactions tank) of 1/4 to 1/2 hp per thousand cubic feet have been found to be adequate.[67] Static-media reactors, of course, do not have these power requirements.

Other Pertinent Information Necessary for Process Evaluation

Denitrification depends on whether or not treatment system conditions are favorable for the growth of the denitrifying microorganism. Important variables include:

1. Sufficient organic carbon
2. Anaerobiosis
3. Absence of inhibitors

[67] *Nitrification and Denitrification Facilities--Wastewater Treatment* (USEPA, August 1973).

4. Proper pH

5. Sludge production

6. Proper temperature

Since the design of denitrification facilities has been based on empirical data influenced by these six environmental factors, each factor will be discussed as it pertains to the operational performance of denitrification facilities.

Organic Carbon Source

In organic carbon removal applications (e.g., activated sludge), dissolved oxygen is introduced into the reactor by aeration so that biological oxidation of the organic matter can take place. In this process of carbon oxidation, oxygen is consumed, being the electron acceptor in the oxidation process.

Since the bacteria cultivated in the denitrification reactor are heterotrophic organisms, denitrification can be carried out only if the organisms are supplied with an organic energy source termed the electron donor (usually methanol). Thus, in the process of denitrification, the electron donor is oxidized under anaerobic conditions with nitrate or nitrite (instead of oxygen) serving as the electron acceptor.

Thus, in denitrification (as opposed to organics removal), it is the nitrate that is the pollutant which must be removed and the carbon source that is added. In organics removal, it is the carbon which is the pollutant to be removed and the oxygen that is added.[68]

Nitrification removes the organic carbon (energy source) present in raw domestic sludge. Many industrial and agricultural wastewaters do not contain suitable electron donors; one way of overcoming these limitations is to add organic material (to serve as an electron donor) under carefully controlled conditions.

The choice of the carbon (energy source) is important both technologically and economically. Therefore, the following parameters should be considered when choosing an electron donor:[69]

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[68] *Process Design Manual for Nitrogen Control* (USEPA, October 1975), p 5-1.

[69] M. H. Christensen and P. Harremoës, *Biological Denitrification in Water Treatment--A Literature Study*, Report 2-72 (University of Denmark, 1972).

1. Cost of the compound

2. Donor availability

3. Reaction of the donor with nitrates.

Numerous reduced organic substances have been tested successfully as a carbon source, including acetic acid, acetone, ethanol, methanol, and sugar. Methanol is preferable in most applications, because it exhibits certain advantages over other carbon sources. First, it is free of contaminants such as nitrogen, and therefore can be used directly without taking the special precautions necessary for using certain other carbon sources. Second, the product is of consistent quality, while other sources may vary in strength and composition either daily or seasonally, complicating process control and optimization. Use of certain other sources will require regular assaying of the source to check its purity, strength, and biological availability. Methanol also has the advantage of being nationally distributed, while other suitable carbon sources may not be geographically close to the point of use.[70] In addition, methanol is currently the cheapest commercial source of carbonaceous matter, with glucose being the second cheapest source. Methanol is preferable because it is more completely oxidized than glucose and consequently, produces less sludge for disposal.[71]

Methanol (CH_3OH) has a variety of names (methyl alcohol, carbinol, and wood alcohol and is normally supplied pure (99.90 percent). It is a colorless liquid, and noncorrosive (except to aluminum and lead) at normal atmospheric temperatures.[72]

If taken internally, methanol is highly toxic. Inhalation of its vapors is harmful, as is prolonged or repeated skin contact with its liquid or vapors. Fire and explosion are the primary dangers of using methanol, and personnel who handle it should be aware of these hazards.[73] The amount of methanol used must be regulated very closely to prevent odors caused by the conversion of sulfates to hydrogen sulfide. Excessive use of methanol is not only a waste of chemical, but also creates an undesirable residual BOD, which might violate effluent requirements.[74] Therefore, the amount used should be limited

[70] *Nitrification and Denitrification--Wastewater Treatment* (USEPA, August 1973).
[71] *Nitrogen Control* (USEPA).
[72] *Nitrification and Denitrification--Wastewater Treatment.*
[73] *Nitrification and Denitrification--Wastewater Treatment.*
[74] *Nitrogen Control.*

to what is necessary to react with the nitrite and nitrate and the dissolved oxygen remaining in the wastewater effluent added to the denitrification unit.

The methanol requirement where nitrate, nitrite, and dissolved oxygen are present can be computed using the following empirically derived equation:[75]

$$Cm = 2.47\ N_0 + 1.53\ N_1 + 0.87\ D_0 \qquad \text{[Eq A1]}$$

where:

Cm = required methanol concentration, mg/ℓ

N_0 = initial nitrate nitrogen concentration, mg/ℓ

N_1 = initial nitrite nitrogen concentration, mg/ℓ

D_0 = initial dissolved oxygen concentration, mg/ℓ

Methanol demand for a typical domestic waste water is approximately 60 mg/ℓ.[76]

Dissolved Oxygen

It is generally agreed that complete anaerobiosis is desirable for rapid denitrification. Since most denitrifying bacteria are facultative anaerobes, denitrification can only occur when nitrates can effectively compete with dissolved oxygen as the final hydrogen acceptor in the respiration process. It is therefore obvious that if anaerobic conditions are maintained, the greatest level of nitrate reduction will result.

Thus, it may be said that the role of oxygen in denitrification is generally to suppress denitrification. In fact, Balakrishman[77] found that 6.0 mg/ℓ of dissolved oxygen prevents denitrification.

It should therefore be apparent that if water contains dissolved oxygen, the oxygen must be removed before denitrification will occur.

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[75] Metcalf and Eddy, Inc., *Wastewater Engineering--Collection, Treatment, and Disposal* (McGraw-Hill, 1972).

[76] M. J. Hammer, *Water and Wastewater Technology* (John Wiley and Sons, Inc., 1975).

[77] S. Balakrishman and W. W. Eckenfelder, "Nitrogen Relationships in Biological Treatment Processes-III. Denitrification in the Modified Activated Sludge Process," *Water Research*, Vol 3, No. 3 (March 1969), pp 177-188.

This can be accomplished by adding more methanol. A commonly used design rule of thumb indicates that 0.67 mg/ℓ of methanol must be added for each mg/ℓ of dissolved oxygen to the removed.

Inhibition and Toxicity

Environmental conditions that are optimum for denitrification are difficult to describe, because all organisms capable of denitrification do not respond alike. However, certain toxic and inhibitory substances may significantly affect denitrification effectiveness.

Since it is generally believed that the biological cultures that flourish in these systems are more sensitive to heavy metal and organic toxins than to conventional activated sludge, the system should be protected against toxicity by pretreatment processes. Pretreatments, such as activated sludge and nitrification, should provide an effluent suitable for denitrification. However, some toxic or inhibitory substances, such as nonbiodegradable solvents, are not completely removed by pretreatment. The reliability of pretreatment under such circumstances depends on source control, such as control of industrial wastes entering the sewer.

Alkalinity and pH Relationships

The denitrification reaction is characterized by alkalinity. A USEPA report[78] states that a value for alkalinity production suitable for engineering calculations is 3.0 mg alkalinity as $CaCO_3$ produced per miligram of nitrogen reduced.

Therefore, periodic or continuous adjustment of the pH of the denitrification reactor's contents may be required to maintain optimum reaction rate conditions.

The optimum pH for denitrification varies with the nitrate or nitrite concentration and the variety of organisms present in the culture. Studies have indicated that the optimum pH for the denitrifying organism ranges from 6.5 to 7.5, while the pH range of 5.8 to 9.2 is probably acceptable.

Sludge Production

Denitrification is characterized by low solids production. However, solids production is contingent upon the carbon source. If a

[78] *Process Design Manual for Nitrogen Control* (USEPA, October 1975).

carbon source such as glucose were used, microorganism growth would be greater because of a higher efficiency in energy capture. Therefore, methanol, because of its low solids yield, exhibits obvious advantages.

The biomass produced using methanol as a carbon source can be calculated as follows.[79]

$$C_b = 0.53\ N_o + 0.32\ N_1 + 0.19\ D_o \qquad \text{[Eq A2]}$$

where

C_b = biomass production, mg/ℓ

N_o = initial nitrate nitrogen concentration, mg/ℓ

N_1 = initial nitrite nitrogen concentration, mg/ℓ

D_o = initial dissolved oxygen concentration, mg/ℓ

To better visualize the low waste solids production from the denitrification process, consider a raw water containg 40 mg/ℓ of nitrate nitrogen and 8 mg/ℓ of dissolved oxygen. The microorganism production from denitrification would be approximately 23 mg/ℓ. The effluent biological solids are generally well flocculated, so they should need no chemical coagulation for removal.[80]

Temperature

The effect of temperature on the denitrification rate is probably similar to its effect on the activity of any mixed bacterial population.

Any application of denitrification in cold climates would require successful operation at temperatures as low as 5°C. It is reasonable to assume that although denitrification probably slows appreciably as the temperature drops, the rate of denitrification is significant at 5°C.[81]

The consensus is that the reaction rate for denitrification doubles for each 5 to 7°C temperature increase in the range of 10 to 20°C, while denitrification is considered to be optimum at 25 to 30°C.

[79]Metcalf and Eddy, Inc., *Wastewater Engineering--Collection, Treatment, and Disposal* (McGraw-Hill, 1972).
[80]P. P. St. Amant and P. L. McCarty, "Treatment of High Nitrate Waters," *Journal of American Water Works Association* (December, 1969), pp 659-662.
[81]M. H. Christensen and P. Harremoës, *Biological Denitrification in Water Treatment--A Literature Study* (University of Denmark, 1972).

Facility Locations

Table A7 is a partial list of biological denitrification facilities under design or construction in the United States.[82]

Recent Related Army Studies

1. U. S. Army Bio-Engineering Research and Development Laboratory (USAMBRDL)

2. Construction Engineering Research Laboratory (CERL)

Request information concerning nutrient removal studies at Fort Detrick, MD.

Manufacturers and Designers

Not applicable.

References

Not applicable.

[82] *Nitrogen Control* (USEPA).

Table A7

Denitrification Facilities Currently Under Design
or Construction in the United States
(Metric Conversion Factor--1 gal = 3.78ℓ.)

Location	Flow (Million Gal/Day)	Type Facility
Washington, DC	300	Suspended Growth System
Tampa, FL	60	Fixed-Film Denitrification
Salt Creek (Chicago), IL	50	Fixed-Film Denitrification
Central Contra Costa, CA	1	Suspended Growth System
El Largo, TX	0.5	Fixed-Film Denitrification
Manassas, VA	0.2	Suspended Growth System
Firebaugh, CA	--	Fixed-Film Denitrification
Midland, MI	0.01	Fixed-Film Denitrification

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