

Decontamination Technologies for Emerging CBRNE Agents: Scoping Study

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1. Background

The technologies relevant to chemical, biological, radiological, nuclear, and explosive (CBRNE) sciences are rapidly evolving. In the meantime, globalization and the information revolution make new technological developments accessible and relatively inexpensive to many nations and even to groups or individuals. This creates risks in the form of emerging threats such as modified or newly-engineered threats. Emerging chemicals are such an area that could have dual uses. For example, pesticides are useful for controlling pest species and removing unwanted plants. However, commercially available current-use pesticides (CUPS) or their modification products may be used as weapons by terrorists creating severe and long-term health and environmental hazards. The rapid development and potential release of engineered nanoparticles (ENPs) has also raised concerns due to their unique properties. These nanomaterials exhibit unique size-dependant properties and/or increased reactivity due to enhanced surface area to volume ratio. However, the same properties that make ENPs attractive for future applications can potentially give rise to hazardous or toxic situations.

Recently, Environment Canada's Emergencies Science and Technology Section (ESTS) conducted a study to evaluate the potential risk of emerging chemicals related to CBRNE threats under the Chemical, Biological, Radiological, Nuclear and Explosives Research and Technology Initiative (CRTI). The study identified 2 quaternary ammonium herbicides (diquat and paraquat) that pose an extreme vulnerability as CBRNE agents for use in oral exposure particularly in fluids due to their high toxicity and water solubility. A total of 13 pesticides were identified as high vulnerability as CBRNE agents and include organophosphorus pesticides (chlorpyrifos, diazinon, malathion) which are neurotoxins, and other pesticides (captan, folpet, tralkoxydim, chlorthalonil, 1,3-dichloropropene, pentachlorophenol, lindane, endosulfan, dicofol, methoxychlor) linked to their potential carcinogenic effects or classification as persistent organic pollutants. For ENPs, the vulnerability was determined to be extreme for Al/Fe₂O₃, Al/CuO, Al/ammonium perchlorate and high for Al/MoO₃, Al/WO₃, Al/BiO₃, P-based nanothermites, TATB, RDX, TNT, CL-20, PAX-28, respectively.

2. Objectives

The objectives of this study were:

- to collect information on existing technologies that have been developed for or can likely be used for decontamination of the emerging threat chemicals identified in the previous CRTI study;
- to analyze available information to determine promising technologies for the target emerging agents;
- to identify technology gaps in emerging CBRNE agent decontamination; and
- to provide recommendations on future direction for decontamination R&D to CSSP

3. Accomplishments

This study compiled information on decontamination technologies for CUPs and ENPs. Based on the available information, the existing technologies were evaluated and decontamination options summarized. Furthermore, this study identified significant gaps in decontamination technology research on emerging threat agents. Specifically, the available decontamination technologies for CUPs are very limited. For ENPs, there are almost no specific decontamination technologies available, except for some laboratory protocols designed for handling nanomaterial spills or disposal. The findings have been reported at the recent CSSP Decontamination Workshop (2012) to provide scientific evidence for decision-making.

4. Results

A review of the literature shows that a number of approaches are available for pesticide destruction and/or removal. These include physical/mechanical removal, chemical degradation, biodegradation, a combined chemical-biological approach, and advanced oxidation processes (AOPs). For example, AOPs can be used for the mineralization of pesticides in the environment. Different oxidants can be harnessed to accelerate the photodegradation process, such as hydrogen peroxide, ozone, metallic salts, or semiconductors. Recent studies also show the potential of nanomaterials (e.g., nano TiO₂ and ZnO) for use in AOPs to enhance the efficiency due to their unique surface area or greater surface energy. However, existing technologies for surface decontamination are limited, particularly for the potential threat agents described above. Some available methods include catalytic methanolysis for organophosphorus pesticides (OPPs), gamma radiolysis for chlorpyrifos, and bio-detoxification of pesticides such as diazinon and chlorpyrifos. For instance, a two-stage decontamination process, which involves methanol extraction and catalytic methanolysis of organophosphorus compounds in the extract, was developed in a recent CRTI study. The tested OPPs including diazinon and malathion exhibited different removal efficiencies from various surface materials. For sensitive equipment materials, the efficiency ranged from 41.9% to 100.0%. For plastic keyboards, diazinon was the easiest OP compound for removal (95.6%) while malathion was found to be difficult to remove efficiently (41.9%). Overall, the currently available decontamination methodologies for CUPs need to be evaluated and optimized. Furthermore, field trials should be conducted to demonstrate advanced decontamination technologies. For ENPs, the available information shows that only some laboratory protocols for addressing nanomaterial spills or disposal are available, a significant gap in ENP decontamination capabilities that needs to be filled.

5. Significance of Results

Two of the greatest concerns regarding terrorist attacks using emerging chemicals are the accessibility of harmful chemicals and the variety of ways that these chemicals can be dispersed. Using relatively low-tech equipment, terrorists can disperse chemicals in various forms including smoke, gas clouds, food, and medicine. For example, terrorists could attack a commercial chemical production plant or transportation site, releasing toxic chemicals into the air; or fly a crop-duster dispersing toxic substances within an urban setting.

This study collected information on decontamination technologies from a wide range of sources including scientific journals/magazines, books, research and technical reports, official documents, information databases, government websites, and internet web pages. Based on the available information, the study found some promising or nascent technologies for potential emerging agents, but all of these technologies need to be further optimized and verified for increasing their technology readiness level to 6 or 7. More importantly, this study identified significant gaps and weaknesses in decontamination technology preparedness for emerging CBRNE threats. This information is useful for decision-makers for planning and adapting to change.

6. Recommendations

The emerging CBRNE threats that we face continue to evolve, therefore we need to identify and prepare for them in advance. It is critical that we have the capability, as a nation, to be resilient when terrorist attacks occur. To be resilient, we must be able to respond quickly and effectively to all emerging threats with the appropriate resources including decontamination technologies.

The analysis conducted in this scoping study shows that existing decontamination technologies aimed to emerging CBRNE threats are very limited. To fill this significant technology gap, major efforts are needed as follows:

- Continue to collect scientific, technical, and intelligence information on non-traditional threats and to identify potential emerging CBRNE agents
- For CUPs: 1) conduct feasibility studies/field trials to identify, optimize and demonstrate advanced decontamination technologies; 2) investigate the persistence of target agents on different surface materials to facilitate new technology development; 3) develop new technologies for target agents
- For ENPs: carry out decontamination technology R&D for target agents