Green Armaments Technology - Energetics Forensics Initiative

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Abstract:

The US Army Armament Research Development and Engineering Center (ARDEC) is sponsoring the Green Armaments Technology (GAT) Program. One goal of the GAT program is to minimize the impacts of energetics contamination on military ranges resulting from testing/training activities. By achieving this goal, the Army will be able to maintain and strengthen its testing/training capability and achieve sustainable ranges. In turn, military readiness can be assured. This paper describes the results of the GAT Energetics Forensics Initiative (EFI), which includes a methodology developed to assist the Army in identifying and prioritizing actions necessary to minimize energetics contamination on ranges.

1.0 Background

The Department of Defense (DoD) has estimated that more than 1400 sites on 10 million acres of land within the United States and at overseas facilities may be contaminated with unexploded ordnance (UXO), explosives, and other hazardous/toxic substances.[1] Much of the contamination resulted from the conduct of essential military training and weapon systems testing that serves the Nation and protects the American people during times of war. In 1997, based on the threat of contamination of a sole source aquifer, the U.S. Environmental Protection Agency (EPA) curtailed artillery and mortar live-fire training at the Massachusetts Military Reservation (MMR), setting a precedent and making it clear that the presence of munition constituents and UXO on military ranges can impact military testing and training capability.[2] Consequently, DoD must proactively respond to concerns regarding the impacts to health, environment, and safety of these activities if it is to maintain access to testing and training facilities vital to maintaining military readiness.

2.0 Objective, Scope, and Approach

This project addresses one goal of ARDEC's overall GAT program—specifically, minimization of the impacts of energetics contamination on military ranges resulting from the use of medium and large caliber mortar and artillery munitions. The approach for this project includes: Phase I – Problem Definition; Phase II – GAT Strategy Development; and Phase III – GAT Demonstration.

The purpose of Phase I was to establish the state of knowledge and identify data gaps regarding range contamination. This was accomplished through a review of over 450 documents identified during a focused literature search, as well as site visits, telephone interviews, and a GAT Workshop (November 2003) with representatives of all the major organizations involved in research related to range contamination. The results of Phase I efforts are described in the report entitled, “State of Knowledge Regarding Military Range Contamination” (dated 30 July 2004).

In Phase II, the information gathered in Phase I was used to identify root causes of range contamination and to develop a GAT Strategy to minimize range contamination. This Strategy included a step-by-step methodology that could be used to facilitate the identification of possible alternatives that might be pursued to minimize range contamination.

In Phase III, the GAT methodology was demonstrated on a specific munition item. The GAT Strategy and the results of the Demonstration are described in the report entitled, “Strategy to Minimize Energetics Contamination at Military Testing/Training Ranges” (dated 29 March 2005).

3.0 Phase I – Problem Definition

As shown in Figure 1, data and information necessary to define the problem of range contamination were grouped into the following categories:

- Sources of Contamination
- Fate and Transport
- Toxicity
- Nature and Extent of Contamination
- Risk Assessment
- Site Remediation

Problem definition is critical for the development of a comprehensive strategy to minimize range contamination because the nature, extent, source, and fate of contamination must be well understood in order to make an informed decision about which changes will best minimize the impacts of energetics contamination on ranges. To develop a sound definition of the problem, research was reviewed related to the data and information inputs shown in Figure 1.

In addition to research that supports the definition of the problem, information on various completed and ongoing green munition studies was gathered for input into the GAT Strategy. Primary findings of this problem definition phase are briefly summarized in Table 1.

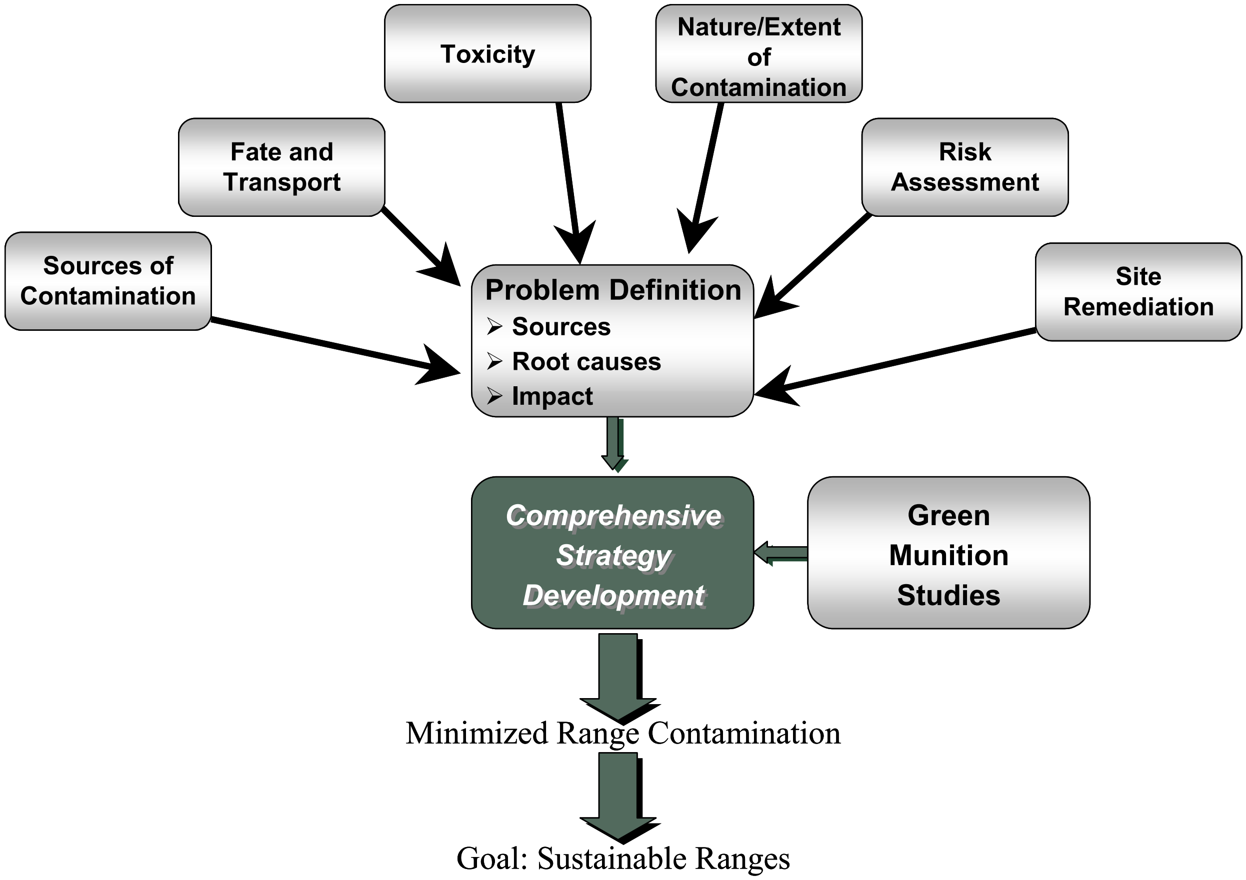

Figure 1: Data and Information Inputs for Strategy Development

Table 1: Primary Findings of Problem Definition Phase

Category	Findings
Sources of contamination	• Low order detonations are the primary source of range contamination. Blow-in-place operations, UXO, and high order detonations contribute to energetics contamination to a lesser extent.
Fate and transport	• RDX is the primary threat to groundwater based on the high transformation rate of TNT, the low sorption of RDX to soil, and greater quantities of RDX used compared to HMX. • The relative importance of process descriptors for TNT, RDX, and HMX can be summarized as follows: Volatilization rate: TNT>RDX/HMX Dissolution rate: TNT>HMX>RDX Solubility: TNT>RDX>HMX Sorption: HMX>RDX Transformation: TNT>>RDX≥HMX
Toxicity	• RDX has been classified as a probable human carcinogen. • Toxicity data can be summarized as follows: RDX: oral RfD = 3E=03 mg/kg-day; oral CSF = 1.1E-01 day/mg-kg; probable human carcinogen[3] TNT: oral RfD = 5E-04 mg/kg-day; oral CSF = 3.0E-02 day/mg-kg; possible human carcinogen[4] HMX: oral RfD = 5E-02 mg/kg-day; human carcinogenicity is not classifiable[5]
Nature and extent of contamination	• TNT, RDX, and HMX have been detected in soil samples at various sites sampled to date. Other energetics were detected less frequently. • Energetic contamination at military ranges tends to be distributed point sources, so sampling procedures must account for the heterogeneity. • On-site analyses should be used as often as possible to characterize or monitor range contamination to permit quick decision-making required for continued range operation.
Risk assessment	• Decisions regarding remediation of energetics-contaminated sites should not be based solely on site characterization data. A clearly-defined risk assessment process, incorporating independent peer review, should be performed with toxicity and exposure assessments to identify the ultimate impact to human health and the environment.

Category	Findings
Site remediation	• Technologies are available for the clean up of energetics-contaminated soil and groundwater, but technologies proven effective at munition manufacturing sites may not be applicable to ranges. • Remediation efforts at active ranges are complicated by access limitations due to hazards associated with UXO and requirements for continued operations. Simple in situ remediation processes are the most appropriate for such sites.
Green munitions	• Alternative materials (including new energetic compositions and lead-free small arms) have been identified and evaluated with mixed results. • Alternative munitions designs (e.g., laser ignition systems to replace primers containing toxic and hazardous materials) and energetic manufacturing processes (e.g., closed-loop manufacturing processes to eliminate volatile emissions) show promising results.

4.0 Phase II – Strategy Development

A comprehensive approach to developing a strategy for minimizing range contamination and achieving the ultimate goal of sustainable ranges addresses all stages of the range munition lifecycle as shown in Figure 2. In Phase II of the initiative described in this paper, a GAT Strategy for minimizing range contamination was developed with a focus on modifications to the design and manufacture stage of the munition lifecycle.

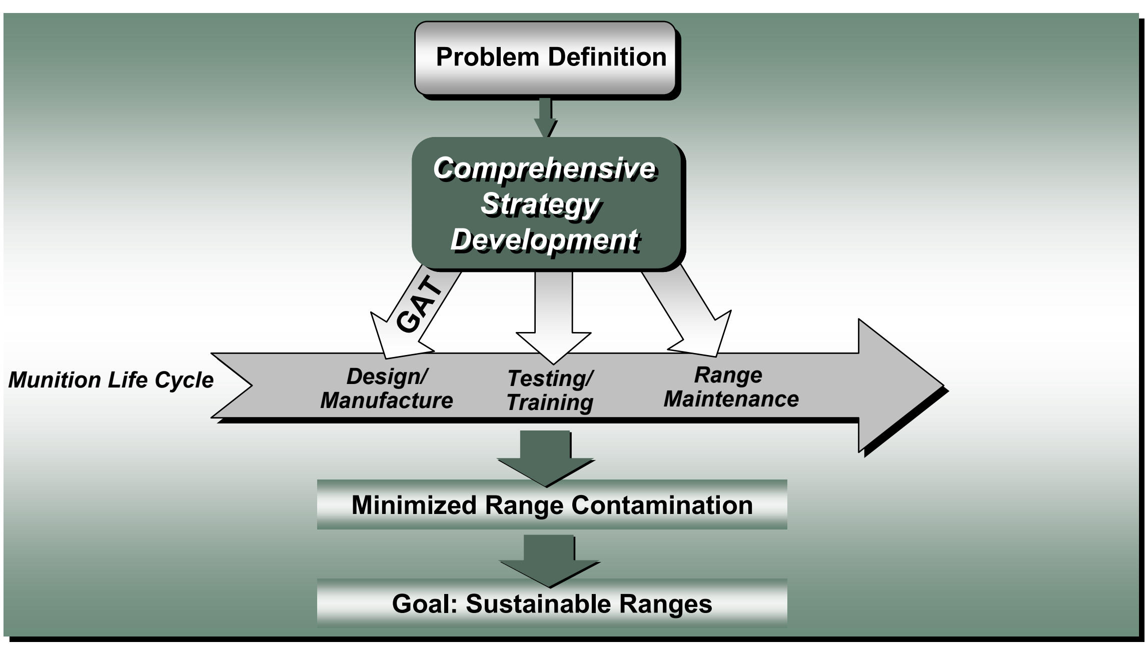

Figure 2: The GAT Strategy focuses on Changes to the Design/Manufacturing Phase of the Munition Life Cycle

The GAT Strategy includes a methodology to ensure that a systems engineering approach is consistently applied, and that all impacts are considered, when identifying, prioritizing, and recommending munition design and/or manufacturing changes to minimize range contamination. This methodology has been developed to provide guidance and to be general enough that it can be applied to any munition item. Elements of the GAT methodology include:

1. Selecting a Munition Item for Analysis - The first step of the GAT methodology is to select a munition item to be analyzed to determine if any opportunities exist to minimize energetics contamination by modifying the design/manufacturing phase of the munition life cycle.

2. Reviewing Systems Requirements - Once a munition item is selected for analysis, the original systems requirements for the integrated weapon system should be reviewed to ensure that the design rationale is well understood and that opportunities and alternatives identified in the subsequent steps of the GAT methodology do not negatively impact the overall system performance.

3. Identifying Potential Alternatives - After the munition item has been selected and the systems requirements for that item have been reviewed, opportunities in the design/manufacturing phase of the munition life cycle should be examined in order to identify alternatives for minimizing energetics contamination on military ranges.

4. Applying Threshold Criteria - Once a list of specific alternatives has been developed, threshold criteria should be applied to refine the list of alternatives. The alternatives that pass the threshold criteria should move forward in the process for further assessment.

5. Rating/Ranking Alternatives - Alternatives that pass the Threshold Criteria should be assessed based on Evaluation Criteria and associated weighting factors to rate and rank the potential alternatives. The evaluation criteria allow for a comparison between baseline and other alternatives.

6. Selecting Alternatives - Once consensus is reached regarding the rating of each criterion, the alternatives that appear to have the greatest positive effect with the least amount of negative impacts should be recommended for possible implementation.

5.0 Phase III - GAT Demonstration

The GAT Strategy developed in Phase II was demonstrated by applying it to the 155mm Howitzer M107 round. This demonstration involved a team of experts involved in munition design, manufacturing, and Load/Assemble/Pack (LAP), and storage. First, the systems requirements were reviewed based on information from the Technical Manual TM43-0001-28, Munitions Items Disposition Action System (MIDAS) and other sources. Alternatives were then identified in the opportunity areas shown in Table 2.

Table 2: Areas of Opportunities and Targets for Minimizing Range Contamination

Target	1. Eliminate Energetics ➢	2. Substitute Energetics ➢	3. Reduce Energetics ➢	4. Maximize Reliability ➢	5. Minimize Environmental Impact
Design	A. Propellant B. Fuze C. Main Charge	A. Propellant B. Fuze C. Main Charge	A. Propellant B. Fuze C. Main Charge	A. Propellant B. Fuze C. Main Charge D. Integrated Platform E. Packaging	A. Prevent Exposure
Manufacture				F. Propellant G. Fuze H. Main Charge I. Hardware/ Metal Parts	
LAP				J. Facilities K. Operations	
Storage				L. Age & Climate	

Thirty-three alternatives were identified and subjected to a preliminary evaluation against four specific threshold criteria: mission readiness, safety, range sustainability, and implementation feasibility. During this threshold evaluation, six alternatives were eliminated. The remaining 27 alternatives were then rated and ranked based on their response to weighted criteria including effectiveness, cost, and schedule.

Based on the outcome of the rating and ranking of alternatives, seven alternatives were recommended for further consideration. (It should be noted that the demonstration participants strongly believed that the user community should be consulted prior to recommending implementation of any alternatives.) The recommended alternatives were those that involved the use of various training rounds and the incorporation of self-destruct fuzes and include:

1. Eliminate the main charge by using the existing technical data package to produce the M804A1 with cast iron.
2. Increase the use of the M804A1 training round.
3. Modify the M804A1 training round to increase the signature.
4. Modify the M107 round with inert filler and a smoke charge in an aluminum liner.
5. Substitute the main charge with an ammonium nitrate filler in a training round.
6. Substitute the main charge with 2,4,6-Trinitrotoluene (TNT) in a dual use round.
7. Include a self-destruct feature in the M767 and MOFA fuzes.

6.0 Conclusions

ARDEC now has a GAT Strategy that can contribute to Range Sustainability and Mission Readiness by identifying opportunities for design and manufacturing changes that minimize the potential for energetics contamination on military testing and training ranges. The Strategy can be applied early in the design of a new munition item but also has application in efforts to redesign/modify existing munition items.

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[1] Defense Science Board Task Force on Unexploded Ordnance December 2003.

[2] AMEC Earth & Environmental, Inc. (2003, February 2003). *Draft Rapid Response Action/Release Abatement Measure Plan Demo I Soil Operable Unit*. MMR-7096, prepared for National Guard Bureau, Massachusetts Army National Guard, and U.S. Army Corps of Engineers.

[3] Integrated Risk Information System (IRIS) *Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) (CASRN 121-82-4)* Environmental Protection Agency, Washington, DC. http://www.epa.gov/iris/

[4] Integrated Risk Information System (IRIS). *2,4,6-Trinitrotoluene (TNT) (CASRN 118-96-7)* Environmental Protection Agency, Washington, DC. http://www.epa.gov/iris/

[5] Integrated Risk Information System (IRIS) *Octahydro-1,3,5,7-tetranitro-1,4,5,7-tetrazocine (HMX) (CASRN 2691-41-0)* Environmental Protection Agency, Washington, DC. http://www.epa.gov/iris/