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SOIL COMPOSTING FOR EXPLOSIVES REMEDIATION: CASE STUDIES AND LESSONS LEARNED

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SOIL COMPOSTING FOR EXPLOSIVES REMEDIATION: CASE STUDIES AND LESSONS LEARNED

1. Purpose.

a. This Public Works Technical Bulleting (PWTB) presents case studies and lessons learned from several Army cleanup sites where composting has been implemented as a remediation technique for soils contaminated with explosives and nitroaromatic materials. Composting has presented various advantages, including cost savings, over incineration which is another common method used for remediation of explosives-contaminated soil. This document provides guidance and recommendations for future implementation of composting as a remediation technique.

b. All PWTBs are available electronically (in Adobe® Acrobat® portable document format) through the World Wide Web at the National Institute of Building Sciences' Whole Building Design Guide web page, which is accessible through URL:

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability. This PWTB applies to all U.S. Army Corps of Engineers (USACE) Districts and Department of the Army installation personnel responsible for the remediation of explosives-contaminated soils.

3. References.

a. Army Regulation (AR) 200-1, "Environmental Protection and Enhancement," Ch. 12-3, 13 December 2007.

4. Discussion.

a. The goal of AR 200-1, Chapter 12-3, is to perform appropriate and cost-effective cleanup so that property is safe for Army use or transfer (as appropriate), sustains operations and training, and protects human health and the environment.

b. Explosives contamination in soils is a common problem at many Army sites. According to the Remediation Technologies Screening Matrix, the Department of Defense (DoD) has been evaluating composting systems to treat explosives waste since 1982. To date, composting has been shown to degrade explosives compounds (e.g., TNT, RDX, HMX, DNT, and Tetryl) and nitrocellulose in soils and sludges. Composting is a process in which organic wastes are degraded by microorganisms at elevated temperatures under both aerobic and anaerobic conditions. The main advantage of this technology is that, unlike incineration, composting generates an enriched product that can sustain vegetation. After cleanup levels are achieved, the composted material can be returned to the site.

c. Composting has been implemented in various Army contaminated sites, including Umatilla Chemical Depot (UMCD) and Joliet Army Ammunition Plant (JOAAP). In the case of UMCD, the Army saved more than $2 million using composting compared to other technologies such as incineration. Lessons learned from the implementation of composting to solve explosive contamination problems in soil will be applicable to other contaminated sites, including Army training ranges and property now designated as Formerly Used Defense Sites (FUDS).

d. Appendix A is an introduction to the use of composting for remediation of explosives-contaminated soils and its use at DoD sites. This appendix provides information about the main characteristics of the system such as temperature, moisture, oxygen, carbon-to-nitrogen (C:N) ratio, and amendments. This appendix also provides cost data.

e. Appendix B describes four case studies where composting has been selected as the remediation technology for cleanup of soil contaminated with explosives compounds. These case studies include the following sites:

- Joliet Army Ammunition Plant (JOAAP), Joliet, IL
- Plum Brook Ordnance Works (PBOW), Sandusky, OH
- Milan Army Ammunition Plant (MLAAP), Milan, TN
- Umatilla Chemical Depot (UMCD), Hermiston, OR

Discussion of the cases includes site background, description of the contamination present at the site, remediation alternatives evaluated before the final selection of composting, and how the composting process was approached. Table 1 summarizes the cases comparing the rate and cost of the soil remediated at each site.

Table 1. Case studies summary.

Site	Contamination Description	Approximate Amount Remediated (tons)	Approximate Cleanup Rate (days/windrow)	Cost ($/ton)
JOAAP	TNT, DNT, Tetryl	274,000	17-21	84
PBOW	Nitroaromatics	5,200	28	*
MLAAP	TNT and RDX	17,400	20	1,025
UMCD	TNT, RDX, HMX, Tetryl	14,808	10-12	346

**Ongoing project, final cost was not available.*

To facilitate the identification of contaminated areas, the sites are usually divided into Operable Units or Remediation Units, which are discrete actions that constitute incremental steps towards the final remedy. The actions could (1) address a specific geographical area of the site or (2) affect a specific problem. For instance, if units are divided by a specific problem, groundwater and soil contamination could be in the same geographical area but in different units, because the treatment applied would be different in each case.

f. Appendix C contains lessons learned for composting as a remediation technology. These lessons were compiled after studying different sites and reviewing site documentation that included, among other documents, the Records of Decision, Feasibility Studies, and Final Removal Action Reports. Conversations with U.S. Army Corps of Engineers districts and Army Environmental Center personnel in charge of the different projects also contributed to this appendix. The recommendations provided are related to optimization of the system, infrastructure, costs, communication, etc.

g. Appendix D lists the references used to prepare this document.

h. Appendix E lists acronyms used in this PWTB. It also includes a chart that may be used to convert the inch-pound measurements to the international system (SI) of measurements if needed.

5. Points of Contact.

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APPENDIX A

INTRODUCTION

Composting has been defined as a system that uses microbial activity to degrade and reduce the quantity of organic materials while providing relatively stable end products (USEPA 1998) through biochemical processes of decomposition and conversion of organic substances to humic constituents. The composting process is initiated by mixing the biodegradable organic matter with bulking agents and other amendments. The degradation of the contaminants is achieved by manipulating the moisture, temperature, oxygen, and carbon-nitrogen (C:N) ratio of the contaminated soil. These manipulations are achieved by the addition of amendments.

Due to its effectiveness for degrading explosives and nitro-aromatic compounds, the use of composting as a bioremediation technique has become widely used within the Department of Defense (DoD) cleanup sites. Composting has presented various advantages over incineration which is another common method used for remediation of explosives-contaminated soil. These advantages include cost savings and minimizing the release of hazardous products to the atmosphere. Table A-1 lists sites that have used composting to remediate contaminated soil.

Table A-1. Army sites using windrow composting for remediation.

Site Name	**Soil Quantity (yd^3)**
Hawthorne AD[a]	64,000
JOAAP	>200,000
MLAAP	>58,000
Newport AAP[b]	9,000
Pueblo AD	21,000
Sierra AD	2,000
Tooele AD	15,000
PBOW	5,100
UMCD	15,000

[a]Army Depot [b]Army Ammunition Plant

(Source: Spain et al. 2000)

The composting process consists of placing the soil on an impervious surface in elongated piles known as windrows. Periodically, the soil is mechanically turned by using mobile equipment known as a windrow turner (Figure A-1). The purpose of turning the soil in the windrows is to aerate the mixture, distribute heat and moisture, and mix the amendments with the contaminated soil to ensure even composting.

Figure A-1. Windrow being turned by a windrow turner at PBOW.

Important Characteristics of the Composting Process

Moisture – The optimum moisture content for bacteria in compost is between 50% and 60%. When the moisture content is above 60%, the airflow is restricted and anaerobic conditions will be generated.

Oxygen – Composting is a highly aerobic system. It is critical for the system to have efficient oxygen levels in order to break down organic material. The oxygen levels may be regulated by optimizing moisture, turning the windrows frequently, or by adding amendments to control aeration.

Temperature – Changes in temperature in the composting process are caused by the microbial activity present. As the microorganisms grow, their metabolic activity increases the temperature of the system. Although higher temperature is beneficial in many ways, the microorganisms and enzymes are inactivated and the composting process will stop beyond 140 °F (Ro et al. 1998).

C:N Ratio - The compost microorganisms require adequate levels of carbon sources and other nutrients, including nitrogen, phosphorous, sulfur, and other trace minerals. Among these, carbon and nitrogen are the limiting substrates. The C:N ratio of the remediation compost mix can be manipulated in order to promote degradation of explosive compounds that usually contain a significant amount of nitrogen (Ro et al. 1998). A ratio of 30:1 is considered optimal.

Amendments - To achieve an effective composting process, a blend of different materials (amendments) should be created in a way that allows all the critical characteristics explained above to reach their optimal conditions. Amendments can be classified in three different classes: bulking agents, nutrient sources, and inoculum. Table A-2 lists common amendments and their function in the composting system. Selection of the amendment materials will be based on many factors, including the local availability of the product. However, the amendment combination ratio should be selected after performing laboratory and pilot tests with the contaminated soil itself to identify the most efficient percentage of amendments needed to achieve the remediation goals established for the cleanup project.

Table A-2. Common amendments used for composting bioremediation.

Nitrogen Sources	Carbon Sources and Bulking Agents for Aeration
Manure (cattle, pig, chicken) Corn-processing waste Silage or hay	Wood fines (sawdust, wood bark mulch, wood chip mulch, straw) Stable bedding Cotton gin trash

Costs

Composting costs are considerably less than the cost of other remediation technologies such as incineration, which is also widely used. The bulk of the cost for composting is influenced by the investment in construction of the treatment facility.

However, after investing in the treatment facility, the larger the amount of soil to be remediated, the lower the cost per ton will be. This is very noticeable when comparing sites, such as JOAAP and MLAAP, for example. Both sites invested in large treatment facilities but JOAAP treated a larger quantity of soil and that is why the difference in cost is so large (refer to Table 1).

Table A-3 lists elements that should be considered when estimating costs for a windrow composting project. Each cost element includes components of labor, equipment, and supplies that can add significantly to the total cost of the project. The elements are divided between fixed costs and variable costs. Fixed costs do not depend on how much soil has to be remediated—these are tasks that will always have to be done. On the other hand, variable costs will depend on the amount of soil to be remediated (USAEC 1996).

Table A-3. Composting cost elements.

Fixed Costs	Variable Costs
Mobilization	Analytical Work
Preparatory Work	Monitoring
Construction of Composting Facility	Sampling
Site Restoration and Demobilization	Testing
	Analysis
	Amendments

APPENDIX B

COMPOSTING CASE STUDIES

Case #1: Joliet Army Ammunition Plant

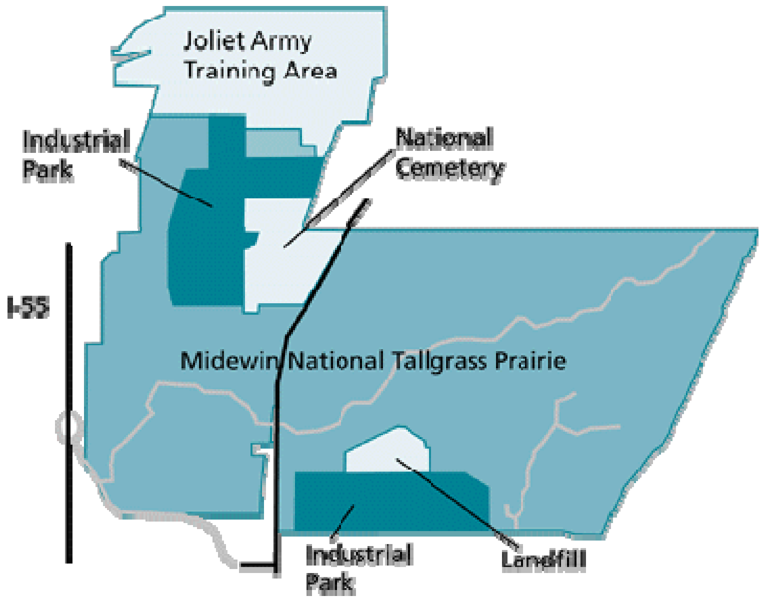
Site Background

The site of the former Joliet Army Ammunition Plant (JOAAP) is in Will County, 40 mi southwest of Chicago, Illinois, south of Joliet, near the town of Elwood. The 23,500-acre facility was established to support World War II (WWII) efforts in 1940 as Elwood Ordnance Plant and the Kankakee Ordnance Works. The site was divided into two main areas. The eastern side of the plant was used to load, assemble, and pack the bombs, shells, mines, and supplementary charges. It was known as the Load, Assemble and Pack (LAP) Area. The western side of the plant, known as the Manufacturing Area (Mfg), was equipped to produce explosives such as trinitrotoluene (TNT), dinitrotoluene (DNT), trinitro-phenylmethylnitramine (Tetryl), and constituent chemicals. At peak production during WWII, the two plants employed more than 10,425 people.

In 1945, the plants were deactivated and combined, then renamed the Joliet Arsenal. Production resumed from 1952–1957 in support of the Korean War; operations were then placed on hold again. The plant was reactivated for the Vietnam War and renamed as JOAPP. Production at the plant gradually decreased until it stopped completely in 1977.

Due to JOAAP’s manufacturing practices, both soil and groundwater became contaminated with explosives compounds, metals, organics, polychlorinated biphenyls (PCBs), sulfur, and hazardous and non-hazardous debris. For this reason, the U.S. Environmental Protection Agency (USEPA) placed JOAAP’s manufacturing and LAP sites on the National Priorities List (NPL) in July 1987 and March 1989, respectively. (The NPL is intended primarily to guide the USEPA in determining which contaminated sites warrant further investigation.) A first Record of Decision (ROD) was signed in October 1998. A second ROD, to cover several interim sites, was later submitted and signed in June 2004. Remedial actions started in May 1995.

After remediation efforts were completed in 2008, most of the site’s land was transferred to various federal and state entities. Figure B-1 is a conceptual map of the planned land transfer activities for the JOAAP site.



Map of proposed future uses for the Joliet site.

Figure B-1. Proposed land transfer activities for the JOAAP site. (Source: *http://www.epa.gov/fedfac/documents/pip6.htm*)

Site Contamination Description

For treatment purposes, the site was divided into different contamination units depending on the nature of the contaminant present. These units were designated as Groundwater Remediation Units (GRUs) or Soil Remediation Units (SRUs). For every unit, a different remediation treatment was selected (USEPA 1999).

Seven SRUs were established to classify the sites:

SRU1 – Explosives in Soil
SRU2 – Metals in Soil
SRU3 – Explosives and Metals in Soil
SRU4 – PCBs in Soil
SRU5 – Organics in Soil
SRU6 – Landfills
SRU7 – Sulfur

This case study will analyze SRU1 and SRU5 remediation efforts. These units represent the soil contaminated with nitroaromatic compounds, the greatest concern at this site. SRU1 and SRU5 were present in several areas of the site.

Remedial Alternatives

The following remediation activities were evaluated for the treatment of explosives present in SRU1 at the JOAAP site (USEPA 1999):

1. ***No Action*** – This alternative was evaluated to establish a baseline for comparison to other alternatives. Under this alternative, no action would be taken to prevent exposure to the contaminated soil.

2. ***Institutional Controls*** – This alternative would reduce the probability of physical contact with the contaminated soil; it included restrictions in excavation, placing of fences and signs, and specification of the risk associated with the use of the land. Natural attenuation processes (the use of naturally occurring processes for cleanup) were also considered as part of this alternative.

3. ***Bioremediation*** – Ex-situ bioremediation uses microorganisms under controlled conditions to degrade explosives contaminants in excavated soil, sludge, and solids. The microorganisms break down the explosives into non-toxic end products by using them as a food source. The end products typically are carbon dioxide (CO_2). Different kinds of ex-situ bioremediation technologies were evaluated before selecting composting as the technology to use for remediation:
   - ***Bioslurry Phase Bioremediation***: soils mixed in water to form a slurry.
   - ***Solid Phase Bioremediation***: soils placed in a cell or building and filled with added water and nutrients. ***Land farming*** and ***composting*** were evaluated as types of solid phase bioremediation.

   Final selection of bioremediation treatment was based on the following factors:
   - cost,
   - technical feasibility,
   - performance time,
   - environmental acceptability, and
   - reuse of the final treated material.

4. ***On-site Incineration*** – This alternative would consist of mobilizing a transportable thermal destruction unit (incinerator) with its associated air pollution reduction accessories. Operation of the incinerator would be 24 hours per day at an estimated feed rate of 20–30 tons of soil per

hour. Normal operation of the incinerator would produce bottom ash (treated soil) from the incinerator, fly ash from the scrubber/baghouse assembly, and gaseous emission from the stack. Treated soil or ash and the fly ash would be disposed at a Resource Conservation and Recovery Act (RCRA) Subpart D facility.

5. *Excavation and Disposal* – This alternative would consist of excavating the soil, loading it into trucks, and transporting it to a central area for stockpiling. After transporting the soil, confirmatory sampling will be performed to determine whether the soils are RCRA hazardous wastes and whether remediation goal concentrations are exceeded. After testing and classifying the soils, an appropriate disposal method would be selected.

Composting Activities

The JOAAP composting facility was constructed in July 1999 and was designed to treat up to 40,000 tons of contaminated soil per year. According to USACE Louisville District documents, by the time it was built, this 20-acre facility was the largest composting facility in the world. Figure B-2 presents an aerial image of the site. As the figure shows, the bioremediation facility included a decontamination building capable of holding about 80,000 cu yd of soil, a 24,000-sq ft soil staging area, an amendment storage building, blending and processing area, a storm water retention basin with capacity for 1 million gallons, and three bioremediation buildings of 100,000 sq ft each with each housing two windrows. The facility was able to house 380-ft long, 25-ft wide, and 10-ft high windrows. The facility also included a treatment material storage area, internal roads for transportation, and an office/laboratory building.

Figure B-2. Aerial view of JOAAP Composting Facility. (Source: http://www.bing.com/maps - Pictometry Bird's Eye)

The amendments used at JOAAP for the composting process included corn processing waste to provide the proper C:N ratio and high moisture content to the mixture. Wood chip mulch and stable bedding were included in the mixture, providing balance with a high C:N ratio and no moisture. These amendment materials, except for the corn processing waste, were obtained locally.

The mixture of amendments was blended in a ratio of 52% stable bedding, 30% percent wood chips, and 18% corn processing waste. This ratio was selected after a prior field demonstration project was performed to evaluate the methodology that was going to be used. During field demonstration, it was determined that the amendments mixture would be pre-blended prior to adding it to the contaminated soil. This pre-blending contributed greatly to reducing the treatment time from 21 days to 17 days per windrow. For treatment, the compost was mixed in a 70:30 ratio of amendments to soil. Figure B-3 shows an example of windrow turning and mixing at the facility.

Figure B-3. Windrow turner at JOAAP.
(Source: http://www.epa.gov/R5Super/fed_fac/npl_sites/ff_npl_jaap_lap.html)

By selecting the correct amendments and using the correct blending and pre-blending strategies, the contractor was able to maintain successful operations at the composting facility, even during cold winter months when temperatures are usually at subzero values. This was accomplished by maintaining a windrow temperature of approximately 85°F (30 °C) and minimum 15%-20% moisture content during the cold months. In the summer, temperatures in the windrows were as high as 140°F (60 °C).

The process had its limitations as well, mostly during the pre-screening process of the contaminated soil. A 6-in. screen was used to remove rocks and debris. However, smaller rocks and other pure explosive aggregates still passed through this screen, limiting the overall efficiency of the process since those materials cannot biodegrade at the same rate as the contaminated soil.

Remediation activities concluded in 2007. By that time, approximately 274,118 tons of contaminated soils were treated. After all required approvals, most of the remediated soil was reused as backfill in some of the excavated areas, including sites M2, L4, M9, and M11. However, these areas are now considered Soil Restricted Areas and do not meet residential standards; its use is limited. Following treatment completion, the composting facility was demolished. The overall cost of the composting treatment was estimated at $84 per ton of soil.

Case #2: Plum Brook Ordnance Works

Site Description

The site of the former Plum Brook Ordnance Works (PBOW) is in Perkins and Oxford Townships, 4 mi south of Sandusky, Ohio, and 59 mi west of Cleveland, Ohio (Figure B-4). The area surrounding the former facility is predominantly agricultural and residential. The property has been occupied by the National Aeronautics and Space Administration (NASA) since 1963, utilizing 6,453.5 acres of the initial 9,009 acres for the NASA Glenn Research Center.

PBOW was built in 1941 as a manufacturing plant for 4,6-Trinitrotoluene (TNT), 2,4-Dinitrotoluene (DNT), and pentolite. During the production period of 1941–1945, more than 1 billion pounds of nitroaromatic explosives were manufactured. The plant was arranged in three separated explosive manufacturing areas: TNT Manufacturing Area A (TNT A) with four process lines, TNT Manufacturing Area B (TNT B) with three process lines, and TNT Manufacturing Area C (TNT C) with five process lines.

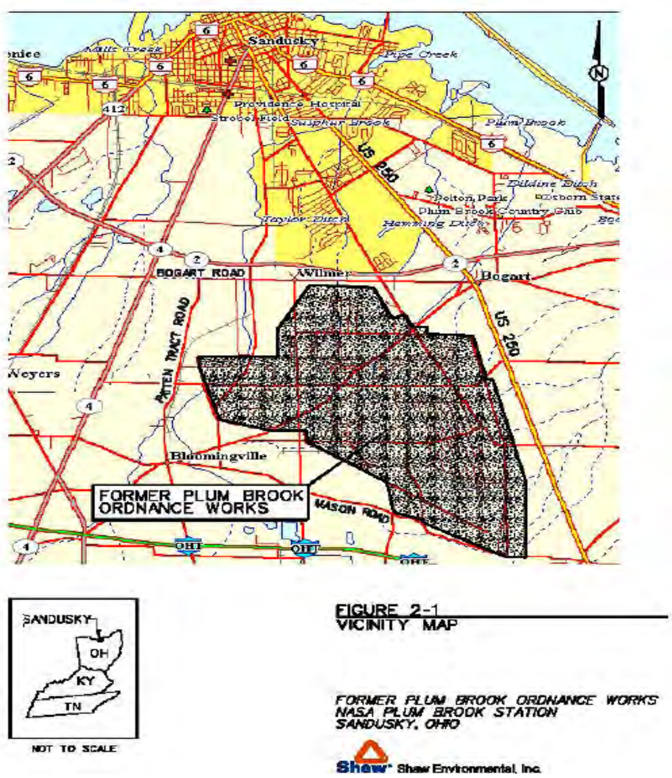


Figure B-4. Plum Brook Ordnance Works site location (USACE 2009).

Site Contamination Description

During operation of the facility, wastewater produced by the purification of TNT within TNT A and TNT B was discharged through wooden flumes and ceramic pipes into various settling ponds such as the West Area Red Water Ponds and the Pentolite Road Red Water Pond. Therefore, nitroaromatic compounds were the major soil contaminants present in the surrounding areas and were included in the decontamination process. The settling ponds were also part of the remediation plan.

Contamination in PBOW was classified and remediated by areas of concern. A total of 16 areas are present in the site, including areas of soil and groundwater contamination. The cleanup actions were focused on nitroaromatics contamination due to past manufacturing practices and consequent spills, leaks, etc. However, lead, PCBs, and other contaminants are also present, but to a lesser extent. The following areas underwent or will undergo remediation at PBOW. For the purpose of this case study, only the Pentolite Road Red Water Ponds will be discussed.

TNT Manufacturing Areas

TNT A

This TNT manufacturing area consists of approximately 113 acres located at the northeastern part of the facility. An estimated 4,777 cu yd of nitroaromatic-contaminated soil are planned to be remediated by using a process that will include: excavation, alkaline hydrolysis, chemical stabilization, windrow composting and off-site disposal/on-site placement.

TNT B

This TNT manufacturing area is located in the south central portion of PBOW and covers 55 acres. A total of 1,500 tons of nitroaromatic-contaminated soil were remediated by using windrow composting. Some of the soil had to be treated for lead prior to the composting. Remediation work at this area was completed in 2006.

TNT C

This TNT manufacturing area covers 119 acres in the southwestern portion of the site. An estimated 2,310 cu yd of nitroaromatic-contaminated soil is planned to be remediated by using the same process as planned for TNT A including: excavation, alkaline hydrolysis, chemical stabilization, windrow composting, and off-site disposal/on-site placement.

Settling Ponds

1. Pentolite Road Red Water Ponds

   The Pentolite Road Red Water Pond (PRRWP) original dimensions were 200-ft wide, 400-ft long, and 3-ft deep with a storage capacity of 182,000 cu yd of wastewater. The pond was filled by NASA in 1977 and covered an area of about 9 acres. A total of 7,600 cu yd of nitroaromatic-contaminated soil was removed from the area for subsequent remediation by using windrow composting. The composting operation was performed during the summer of 2008, and site restoration activities were completed in December 2008.

Remedial Alternatives

The following remedial alternatives were considered for cleanup of the contaminated soils at PBOW:

1. *No Action* – As with other sites, this alternative is considered as a baseline comparison for other alternatives. As the name implies, this action would mean that no remedial action would be implemented at the site.

2. *Excavation, Windrow Composting, and Off-Site Disposal* – Under this alternative, the soil would be excavated from the site and composted in an existing outdoor composting area. This alternative was selected and successfully performed at TNT B and PRRWP.

3. *Excavation and Off-Site Treatment/Disposal* – Contaminated soil would be excavated and treated in a RCRA hazardous waste treatment storage and disposal facility.

4. *Excavation, Windrow Composting, Chemical Stabilization, and Off-Site Disposal* – The alternative involves a process very similar to alternative 2, but it adds a chemical stabilization step after composting to address other contaminants present, such as lead.

5. *Excavation, Alkaline Hydrolysis, Windrow Composting, Chemical Stabilization, and Off-Site Disposal/On-Site Placement* – Using this alternative, a combination of alkaline hydrolysis and windrow composting would be used to treat the soil contaminated with nitroaromatics. Additionally, the soil would be treated using reagents to immobilize other contaminants such as lead. After treatment, the soil could be placed on site

rather than being disposed of in a landfill. This alternative is being considered for use in sites TNT A and TNT C.

Composting Activities

The PBOW composting site was constructed in April 2008 and is located at the north of the northeast quadrant of the facility. During treatment, a total of 10 windrows approximately 13-ft wide, 6-ft tall, and of varying lengths (around 300 ft) were constructed (Figure B-5). In addition to the composting area, two sumps were built to collect all the surface water flow from the facility. The layout was chosen to facilitate storm water removal, for ease of access around the entire operation, and for ease of access between each of the windrows (McTech Corp 2009).

Chicken manure was added to all of the windrows as a nitrogen source. A front-end loader was used to place the material on top of each windrow, and a windrow turner incorporated the material. A total of 500 cu yd of manure were added throughout the composting process. In addition to chicken manure, straw was also added to the windrows as a bulking agent to provide aeration into the windrows.

Figure B-5. Windrows at Plum Brook Ordnance Works.

The selection of these amendments and the amendment ratio was based on bench-scale testing using three different recipes. The actual windrow recipe used for the system consisted of 70% straw, 25% soil, and 5% manure.

It took approximately 8 weeks to remediate 5,100 cu yd of contaminated soil. During the composting process, the windrows were monitored frequently to check that the ambient air quality, C:N ratio, temperature, moisture, and TNT levels were optimal. The remediated soil remained on site and has been used as a top cover for various projects.

Case #3: Milan Army Ammunition Plant

Site Description

Milan Army Ammunition Plant (MLAAP) is a government-owned, contractor-operated military installation located in central Tennessee, 50 miles east of the Mississippi River, 5 miles east of the city of Milan, and 28 miles north of Jackson (Figure B-6). The 22,436-acre facility started operations in January 1942 with the mission to load, assemble, pack, store, and ship ammunition items such as fuzes, boosters, and small and large caliber ammunition. The government contractors operating the facility have changed over the years. The initial contractor in 1942 was Proctor and Gamble Defense Corporation. By 1947, the facility was operated by U.S. Rubber Co. Operations were placed on hold from 1957–1961 and then reactivated in 1961 to be operated by Harvey Aluminum Sales, Inc. Currently, the site is operated by American Ordnance Systems, Inc.

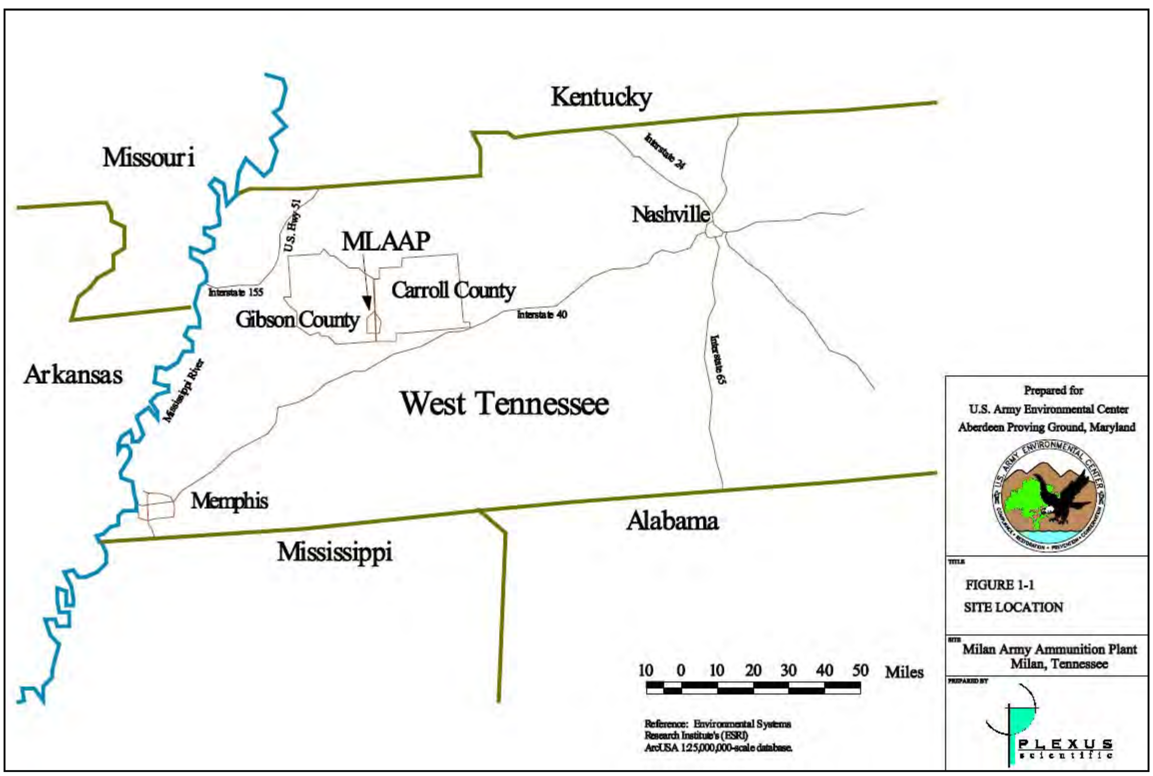


Figure B-6. Milan Army Ammunition Plant site location.
(Provided by Milan Army Ammunition Plant)

Additionally, some of the acreage has been sold, leased, or transferred to the City of Milan, University of Tennessee, and Tennessee National Guard.

MLAAP is currently an active Army installation. To this day, the mission remains loading, assembling, packing, and shipping medium and larger caliber ammunitions. The site infrastructure includes 10 lines for ammunition load, assemble, and package (LAP lines A, B, D, H, I, O, V, X, and Z), 1 washout/rework line, 1 central x-ray facility, 1 test area, 2 shop maintenance areas, 12 magazine storage areas, a demolition and burning ground area, an administrative area, and a family housing area. Currently, 13,600 acres within MLAAP are leased for agricultural use.

Contamination problems at MLAAP are a result of past practices that included the discharge of production wastewater to open ditches that drained from sumps or surface impoundments into both intermittent and perennial streams and rivers. At the present time, these practices have been substituted with the use of seven industrial wastewater treatment plants located within the installation. Explosives such as TNT and RDX were identified as contaminants of concern in the soil and groundwater. Due to the extent of groundwater contamination, USEPA listed the site on the NPL in 1987.

Site Contamination Description

For the purpose of MLAAP restoration, the site was divided into five operable units (OU), depending on the type of contamination:

OU1, Groundwater – This unit is located in the northeast portion of MLAAP and consists of the groundwater underlying approximately 50 acres of LAP Line O and south of Line K.

OU2, Soils, Sediment and Surface Water – This unit is located at the south east portion of the OU1 area. It comprises the soil beneath and around the former ponds, surface water, and shallow sediments. This area is approximate 13 acres.

OU3, Northern Industrial Area Soils and Groundwater – This unit consists of the northeast sector of the facility and comprises nine manufacturing lines (Line B/I, C, D, E, H, K, and O; most of them LAP lines), two storage areas, a closed sanitary landfill, and a salvage yard. In this unit, 10,500 tons of soil were excavated for subsequent treatment.

OU4, Northern Industrial Area Soils and Groundwater – This unit consists of the northwest sector of the facility. This OU comprises six manufacturing lines (Line A, F, G, V, X, and Z; most of them LAP) and two storage areas. In this area, 6,900 tons of soil were excavated for subsequent treatment.

OU5, Southern Study Area – This area comprises all the contaminated soil and groundwater within the entire southern portion of the installation. The area includes the open burning ground and former ammunition destruction area, the ammunition test area, the ammunition storage area, the closed ammunition burnout area, and the closed sanitary landfill.

This case study discusses the remedial actions taken for contaminated soils in the OU3 and OU4 areas. In 1995, an ROD for explosives in soil in OU3 and OU4 was signed describing, among other things, the extent of the contamination and the selected remedy.

Activities in the areas OU3 and OU4 varied from production of munitions to storage of the finished ammunition. Since contamination in the manufacturing lines was very similar, MLAAP 1995 ROD used Line B as a representative of the contamination present in all of the manufacturing lines. Explosive compounds such as 2,4,6-TNT, RDX, and Tetryl were present at an average concentration in the range of 10 µg/g to 100 µg/g, with a maximum concentration of 100,000 µg/g. Remediation goals were set to 10 mg/kg for RDX, 25 mg/kg for 2,4,6-TNT, and 500 mg/kg for Tetryl (USEPA 1995).

Remedial Alternatives

The following are the remedial alternatives considered for cleanup of the contaminated soil at the MLAAP site:

1. *No Action* - This alternative is considered as a baseline comparison for other alternatives. No remedial action would be implemented at the site.

2. *Limited Action* – The purpose of this alternative is to reduce the probability of physical contact with the contaminated soil by implementing a series of actions such as institutional restrictions, fences, and public education programs.

3. *Excavation/Storage/Incineration/Backfill* – By using this alternative, approximately 38,000 tons of soil would be excavated and stored temporarily. The excavated soil would be treated by incineration. After treatment, soil would be used

as a backfill for the areas where the contaminated soil was excavated.

4. *Excavation/Storage/Windrow Composting/Onsite Landfill* – Under this alternative, the soil would be excavated similar to alternative 3. However, the contaminated soil would be treated using windrow composting.

After consideration and detailed analysis, windrow composting was selected as the remedial alternative for the site. The selection was based on the cost advantage this alternative offered in achieving the proposed remediation goals when compared with the incineration option. Additionally, to complement the windrow composting treatment, engineered caps were to be installed in places where excavation was not feasible.

Composting Activities

MLAAP’s composting facility was designed and constructed to process approximately 40,000 tons of soil at a rate of 1,000 tons per month. The facility covers 10 acres and is located north of Highway 54. The facility (Figure B-7) was designed to be flexible enough that it could be reproduced at any other Army installation without significant changes to the design. The facility included the following structures:

Composting building – The composting building had dimensions of 391 X 100 X 22 ft. This pre-engineered metal structure was designed to be completely closed by large automatic doors to allow only truck and windrow turner traffic. The building could sustain three windrows of 14-ft base width, 8-foot crown width, 6-ft height, and 341-ft length.

Amendment storage structure – This structure was designed to have the capacity to store 1 month’s worth of amendments and both treated and contaminated soil. It had a storage capacity of 2,500 cu yd. To facilitate access for the transfer and storage of contaminated soils and amendments, the building had only a roof and open sides. A movable concrete barrier was installed to separate the contaminated soil from the amendments (Plexus Scientific 1998).

Figure B-7. Milan Army Ammunition Plant composting facility.

The amendment mixture used at the MLAAP facility consisted of manure, corn silage, sawdust, and woodchips for bulking. The selection of these amendments was based on an amendment selection study that consisted of the identification and evaluation of locally available ingredients (Plexus Scientific 1998).

By the end of OU3/OU4 remediation efforts, approximately 28,100 tons of soils were treated. This total includes soils from other OUs; there were 17,400 tons of soils removed from OU3 and OU4. Some of the remediated soil, with concentrations of less than 10 mg/kg, was reused as construction material or fill for erosion control in other areas, maximizing the advantages of using this remediation technology. The total cost of the remedial actions for UO3/UO4 was reported to be $1,025 per ton for a total of $17,800,000 (ARCADIS 2009).

The composting facility was decommissioned and placed in a non-operating status in 2008 after completing soil remediation for UO3/UO4. However, it could be reactivated if necessary. Facility decontamination consisted of high-pressure water/steam wash of all buildings and equipment. Decontamination water was drained to a common sump and stored in a 5,000 gal aboveground water storage tank. The water was subsequently treated at the OU4 groundwater treatment plant.

Case #4: Umatilla Chemical Depot

Site Description

Umatilla Chemical Depot (UMCD), originally named the Umatilla Army Depot Activity, was established in 1941 as an Army ordnance depot to store and handle munitions. The facility occupied approximately 20,000 acres located in northeastern Oregon in Morrow and Umatilla Counties, approximately 5 mi west of Hermiston. Activities included disassembly, analysis, modification, reassembly, and repacking of conventional munitions, and the storage of chemical munitions and containerized blister agents. Today, the chemical munitions are the only items still stored at the depot.

UMCD was included in the Army's Installation Restoration Program in October 1978. The facility was later listed for closure by the Base Realignment and Closure (BRAC) Commission in 1988, but it was not closed. Closure was recommended again under BRAC 2005, contingent upon the facility completing its mission. Today, UMCD's sole remaining mission is to safely store and dispose of its chemical ammunition stockpile. The depot will close when all environmental requirements are satisfied and chemical munitions disposal cleanup is completed.

UMCD was the pioneer in the use of composting as a remediation technology in the United States. It was the first full-scale application of this technology for explosives-contaminated soils.

Site Contamination Description

As a consequence of UMCD's explosives handling activities, the soils and groundwater adjacent to the facility became contaminated. The types of contaminants present are explosives compounds, primarily TNT and RDX, in concentrations ranging from 100 to 2000 ppm. Other compounds such as cyclotetramethylene-tetranitramine (HMX) and Tetryl were also present but in lesser amounts. The remediation goal was to reduce concentrations to a target concentration of 30 ppm. To assess the contamination, as with other remediation efforts, the site was divided into eight operable units with different approaches for cleanup:

OU01- Deactivation Furnace Soils - From the late 1950s until 1988, the furnace was used to incinerate unserviceable or obsolete munitions (up to 50 caliber) at the site. These activities have resulted in the contamination of adjacent soil deposits through the windblown deposition of furnace stack and particulates, occasional spilling, and/or on-site dumping of residual furnace ash and munitions incineration debris.

OU02- Washout Lagoons Explosives Soils **-** The water used in the washout process during plant operation was discharged into two adjacent rectangular 10,000-sq ft infiltration/evaporation lagoons. When the plant was operating, a total of approximately 85 million gallons of effluent were discharged into these lagoons. Unit OU02 refers to the soils underneath these lagoons. The remedy was selected in September 1992. It included on-site bioremediation (composting) of 15,000 tons of explosives-contaminated soils. Treatment residues were backfilled on site.

OU03- Explosives Washout Lagoons Groundwater – The remedy was selected in September 1994. It included a groundwater pump and treat system that uses granular activated carbon to reduce the level of contamination in a 350-acre explosives-contaminated groundwater plume.

OU04- Ammunition Demolition Activity Area – The remedy was selected in July 1994. It included excavation, solidification/ stabilization, and on-site landfill disposal of 30,000 tons of soil contaminated with metals and explosives, off-site removal of unexploded ordnance, and implementation of institutional controls to prevent public access to the area.

OU05 - Active Landfill – The selected remedy for this site was no action because site investigations indicated that contamination associated with this site poses no threat to human health or the environment.

OU06 - Miscellaneous Sites – The remedy selected in July 1994 addressed several remaining areas where soils were contaminated with metals. The remedy included excavation, solidification/stabilization, and on-site landfill disposal of 400 tons of metals-contaminated soil.

OU07 - Explosives Washout Plant – This site addresses two major explosives-contaminated areas: (1) the washout plant building and (2) the washout water sump and trough. The remedy, selected in July 1994, included steam cleaning, treating by flash flaming, and demolishing the building.

OU08 – Inactive Landfill – This site includes six discrete former disposal areas totaling an area of approximately 8 acres. After completing investigations, it was determined that this site posed no risks to public health or the environment. No further action was selected.

Based primarily on the contamination discovered at the explosives washout lagoons, UMCD was formally listed on the NPL on 22 July 1987. A remedial investigation and feasibility study of the entire installation, including the lagoons, was initiated in 1990 to determine the nature and extent of contamination and to identify alternatives available to clean up the facility. The first ROD was officially signed in 1992. All remediation efforts have been completed for this site.

Remedial Alternatives

The following alternatives were taken into consideration for the remediation of the explosives contamination in the soils from the OU02 at the UMCD site (USEPA 1992).

1. *No Action* – As for other sites, this alternative is included for comparison purposes.

2. *Thermal treatment (via incineration)* - If selected, this alternative would have involved the excavation of contaminated soils using conventional construction equipment, on-site incineration, and replacement of the treated soil in the lagoon excavation. A clean soil cover would be placed over the top, and the area would be graded and re-vegetated.

3. *Biological treatment (via composting)* - This alternative was the selected remedy for OU02 at UMCD. It involved the excavation of contaminated soils using conventional construction equipment, on-site composting, and replacement of the compost in the lagoon excavation.

Composting Activities

The composting activities at UMCD were conducted as described below.

In June 1994, a 200 x 90-ft prefabricated metal building was constructed for contaminated soil storage. The soil was transported through a concrete staging pad (sloped to a sump for the collection of all contaminated runoff) to the materials process area located adjacent to the storage building where material stockpiling, processing, and drum handling would occur. On 18 July 1995, the full-scale composting treatment started. Thirteen windrow batches containing 810 cu yd and one containing 439 cu yd of contaminated soil were constructed.

After extensive trials, the amendments were selected and the soil and amendment mixture was determined. The mixture was formed of 30% contaminated soil, 21% cattle manure, 18% alfalfa, 10% potato waste, and 3% chicken manure. The amendments were always pre-mixed before mixing with the contaminated soil.

The treatment time on a batch of 810 cu yd of soil (plus amendments) was approximately 10–12 days. Approximately 15,000 tons of contaminated soil was remediated. An estimated 70% of the explosives concentrations were reduced to non-detectable levels. The total cost for remediating 14,808 tons of soil over 2.5 years was $346 per ton. By using composting, UMCD claimed a savings of over $2.6 million compared to other remediation technologies such as incineration.

APPENDIX C

LESSONS LEARNED

After reviewing different sites where composting has been used as the main technology for remediation of explosives contaminants in soil, the following lessons learned have been collected.

Use of Field Test Kits for Environmental Sampling

The use of field test kits with a sufficient number of sample technicians for assessing contamination while excavating the contaminated soil is a great way to expedite the processes of deciding how much area should be excavated. At the JOAAP site, an increased number of sample technicians helped to minimize periods of excavator inactivity during test kit sample analysis. A 1:1 ratio for sample technicians to excavators was optimum for maintaining an efficient excavation/sampling process. Figure C-1 shows an Ensys test kit for explosives detection. This kit was used for field sampling in both JOAAP and PBOW sites. The use of field test kits also reduced the cost of using the fixed laboratory.

Figure C-1. Strategic Diagnosis Ensys — Field Test Kit and Reagents.

Temperature and Moisture Content Control

The success of the composting process depends greatly on keeping the right temperature and moisture content at all times. The ideal temperature for decomposition in the compost windrows is found between 90 and 140°F. Based on experience at PBOW, decomposition is most rapid between these temperatures, below 90°F the process will slow, and above 140°F the microbes may die. For this reason, during winter months, windrows should be turned frequently to keep the needed temperature and moisture content. Keeping the moisture content between 50 and 70% is recommended. However, JOAAP reported moisture contents of 15-20% while PBOW reported an average of 10%. Both sites were able to complete the process even though the moisture content was outside the recommended range.

Amendment Placement

Given the large amount of soil that is placed per windrow, placing the amendment in a step basis rather than placing it all at the bottom of the contaminated soil will improve the mixing process. In PBOW for instance (Figure C-2), after dealing with poor mixing with the large amount of soil on top of the straw layer, the team decided to place the straw in the windrows after every 3 ft of soil instead. This technique improved the mixing of the soil and the amendments, resulting in a faster and more efficient remediation process.

In some cases, the composting process could be further expedited by pre-blending amendments. At the JOAAP site, blending the amendments prior to mixing with the soil resulted in approximately 20% reduction in the composting process time.

Permanent Composting Facility

Constructing a composting facility that could be easily reused is a sensible investment in case more site cleanup projects are needed in the surrounding area. Both PBOW and MLAAP constructed composting facilities that can be easily reused if needed but could have another use in the meantime. In fact, PBOW is reusing the composting facility for their alkaline hydrolysis/composting project for area C soils.

Figure C-2. Straw placement at Plum Brook Ordnance Plant.

Road Construction

Effective transport of soil and amendments to the composting site is critical for the success and timely completion of the cleanup project. After various delays experienced due to soil- and amendment-loaded trucks becoming stuck when the ground was saturated due to rain or snow, the team at PBOW decided to construct a paved road to connect the composting site with the soil and amendment storage area (Figure C-3). This road helped expedite the transport of materials during inclement weather conditions.

Communication

Keeping the community informed by maintaining an open, user-friendly database will increase the community's trust and sense of security in the project. Holding frequent Restoration Advisory Board meetings to discuss remedial alternatives and

Figure C-3. Construction of the paved road in PBOW.

actions is also a must-do activity. In most cases, the community is interested and willing to be a participant in the decisions involved in the cleanup process. Figure C-4 shows a screenshot from an public database maintained by MLAAP.

Documents can be searched by categories or by simple/advanced searches. Results are prompted by date, which makes it easier to find the needed document in such a big database.

In addition to communication with the community, good communication with the contractor is very important for every contracted project. In the case of JOAAP, the open avenues of communication between USACE and the remedial contractor were a key element to facilitating continual smooth operations during their large-scale, multiyear remediation project.

Use of a Single Contractor

To avoid duplicate efforts and associated duplicate costs, the use of a single contractor is recommended for both excavation and remediation of the contaminated soil. UMCD reported that

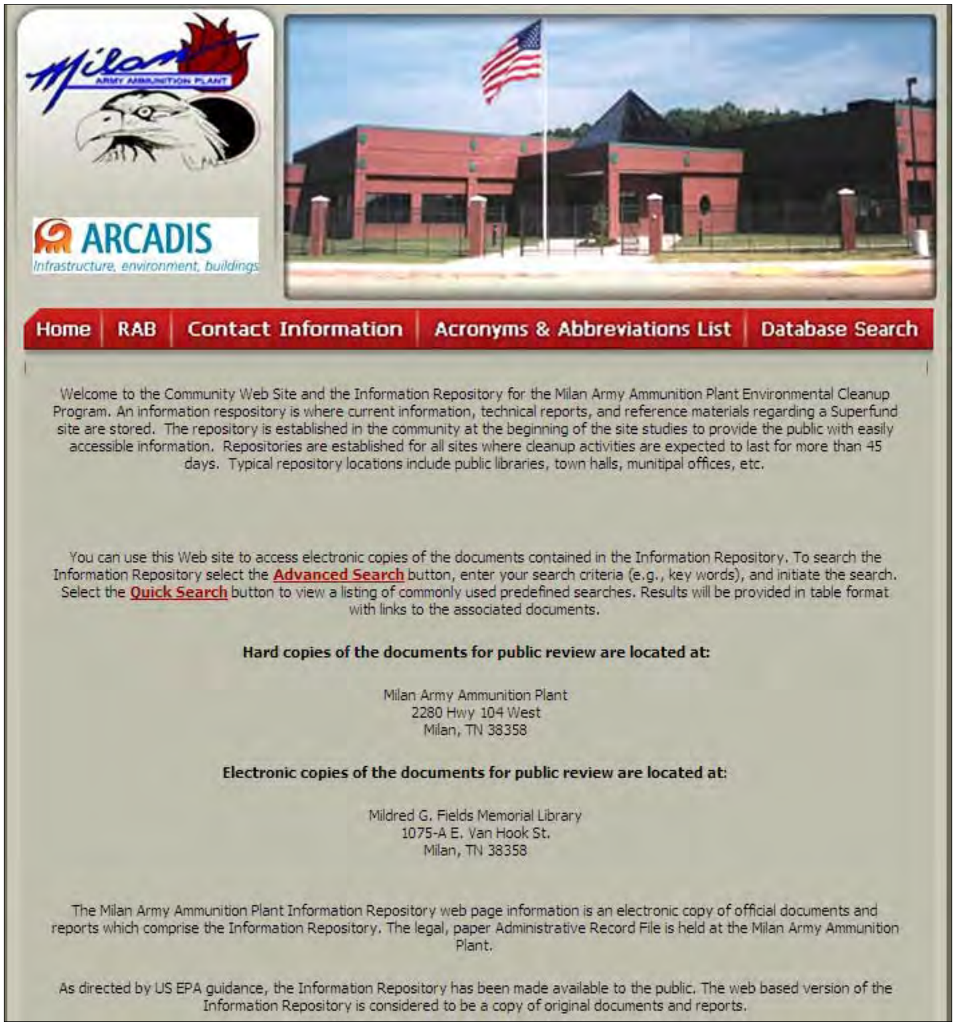


Figure C-4. Public MLAAP document database.
(Source: http://www.milanaap-ar.com/signin.htm)

their unit cost of $346/ton of contaminated soil incorporated the duplication of costs in the areas of mobilization, preparation of the soil, site restoration, and demobilization. In addition to extra work that included re-screening of the soil, temporary storage tents had to be placed due to a lack of interface between the two contractors. Based on their experience, UMDA recommended in their cost report to use a single contractor to run the windrow composting project. By eliminating or reducing some of the costs associated with duplicated efforts, UMDA theoretically would have reduced their unit cost to as low as $299 per ton of soil (USAEC 1996).

APPENDIX D

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APPENDIX E

ABBREVIATIONS AND METRIC CONVERSION CHART

Abbreviations

Term	**Spellout**
AR	Army Regulation
BRAC	Base Realignment and Closure
CECW	Directorate of Civil Works, U.S. Army Corps of Engineers
CEMP-CE	Directorate of Military Programs, USACE
C:N	carbon to nitrogen (ratio)
CO_2	carbon dioxide
cu yd	cubic yard
DNT	2,4-Dinitrotoluene
DoD	Department of Defense
ft	foot
FUDS	Formerly Used Defense Sites
GRU	Groundwater Remediation Unit
HMX	cyclotetramethylenetetranitramine; high melting explosive
HQUSACE	Headquarters, U.S. Army Corps of Engineers
JOAAP	Joliet Army Ammunition Plant
LAP	Load, Assemble and Pack
mg/kg	Milligram per kilogram
MLAAP	Milan Army Ammunition Plant
NASA	National Aeronautics and Space Administration
NPL	National Priorities List
OU	operable unit
PCB	polychlorinated biphenyl
PBOW	Plum Brook Ordnance Works
POC	point of contact
ppm	parts per million
PRRWP	Pentolite Road Red Water Pond
PWTB	Public Works Technical Bulletin

Term	**Spellout**
RCRA	Resource Conservation and Recovery Act
RDX	cyclotrimethylenetrinitramine; royal demolition explosive
ROD	Record of Decision
sq ft	square foot
SRU	soil remediation unit
Tetryl Trinitrophenylmethylnitramine	
TNT 4,6-Trinitrotoluene	
UMCD	Umatilla Chemical Depot
µg/g	micrograms per gram
USACE	US Army Corps of Engineers
USAEC	US Army Environmental Command
USEPA	US Environmental Protection Agency
WWII	World War II

Conversion Chart

This PWTB provides units of measure in the inch-pound system. The following conversion chart may be used to convert measurements to the international system if needed.

Multiply	By	To Obtain
acres 4,04	6.873	square meters
cubic yards	0.7645549	cubic meters
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet 0.30	48	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches 0.02	54	meters
miles	1,609.347	meters
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square yards	0.8361274	square meters
yards 0.91	44	meters