5583

TECHNOLOGY APPLICATION ANALYSIS

Windrow Composting of Explosives Contaminated Soil at Umatilla Army Depot Activity Hermiston, Oregon

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This analysis covers a field demonstration of windrow composting to biodegrade explosives-contaminated soils. The demonstration was conducted from January 1992 to January 1993 to provide information for a full-scale remedial design.

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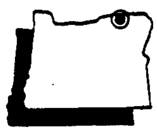
TECHNOLOGY APPLICATION ANALYSIS

SITE

Umatilla Depot Activity (UMDA)
Explosives Washout Lagoons
CERCLA Soils Operable Unit
Hermiston, Oregon



TECHNOLOGY APPLICATION

This analysis covers a field demonstration of **windrow composting** to biodegrade explosives contaminated soils. The demonstration was conducted from January 1992 to January 1993 to provide information for a full-scale remedial design.

SITE CHARACTERISTICS

Site History/Release Characteristics

- UMDA is a 20,000 acre facility established in 1941 whose mission has included storage of chemical munitions and containerized chemical agents as well as the disassembly, assembly, packaging and storage of conventional munitions.
- From approximately 1955 to 1965, UMDA operated a munitions washout facility where hot water and steam were used to remove explosives from munition bodies.
- A total of about 85 million gallons of heavily contaminated wash water was discharged to two settling lagoons.
- Surface buildup of explosives was periodically excavated, but underlying soils and ground water became contaminated.
- Based on investigations initiated in the late 70s and accelerated in 1986 through the RCRA program, the lagoons were placed on the NPL in 1987. UMDA is currently in the Base Realignment and Closure (BRAC) program.

Contaminants of Concern identified in the Risk Assessment are:

Soil:
- 1,3,5-Trinitrobenzene (TNB)
- 1,3-Dinitrobenzene (DNB)
- 2,4,6-Trinitrotoluene (TNT)
- 2,4-Dinitrotoluene (2,4-DNT)
- Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)
- Nitrobenzene (NB)
- Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)

Ground water:
- same as soil plus
- 2,6-Dinitrotoluene (2,6-DNT)
- N,2,4,6-Tetranitro-N-methylaniline (Tetryl)

Properties of contaminants focused upon during remediation are:

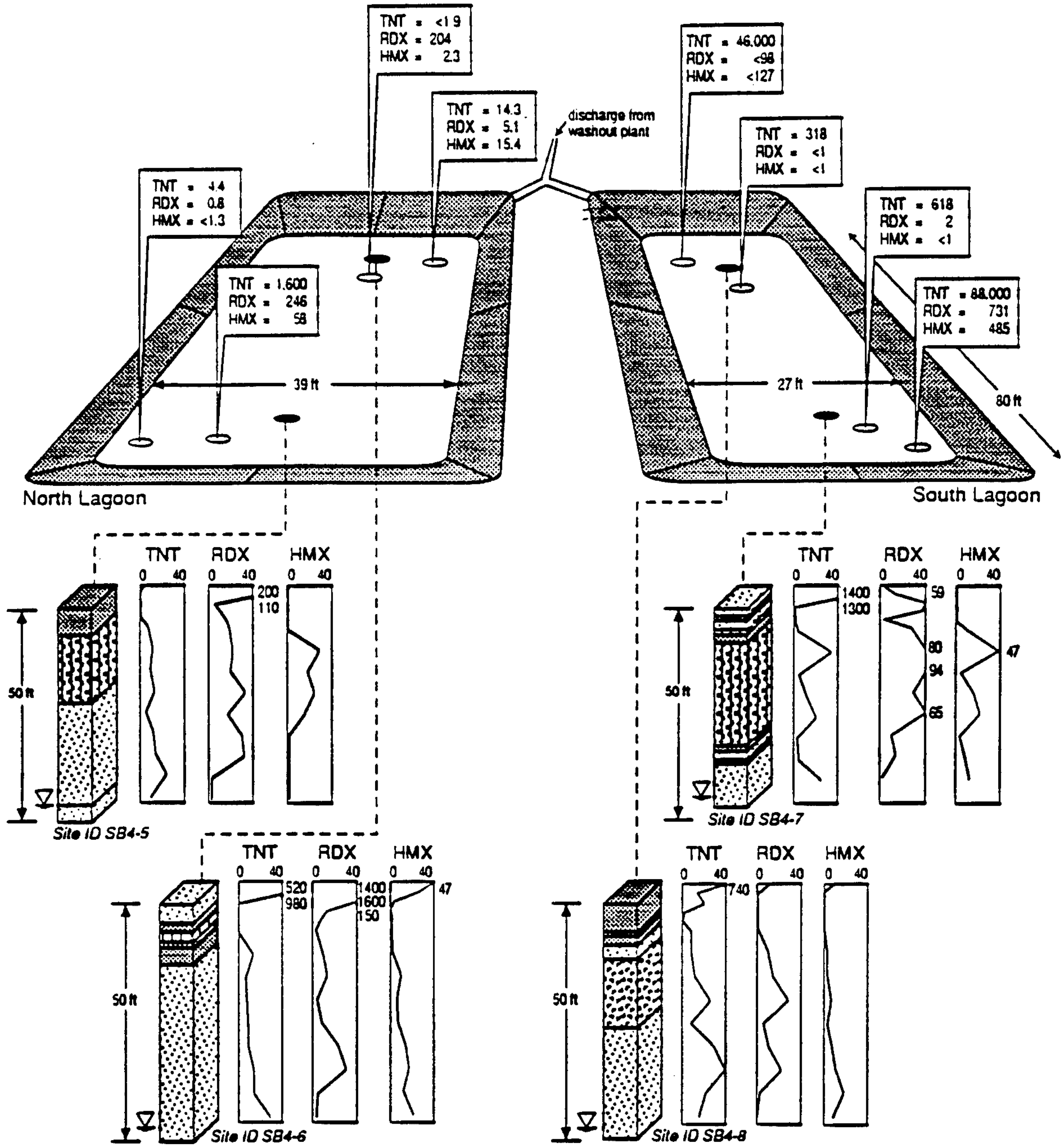
Property at STP*	Units	TNT	RDX	HMX
Empirical Formula	-	$C_7H_5N_3O_6$	$C_3H_6N_6O_6$	$C_4H_8N_8O_8$
Density	g/cm^3	1.65	1.83	1.90
Melting Point	^oC	81	205	286
Vapor Pressure	mmHg	5.51E-6	4.03E-9	3.33E-14
Water Solubility	mg/L	150	60	5
Octanol-Water Partition Coefficient: logKow	-	2.00	0.87	0.26
Site Specific Soil-Water Partition Coefficient: Kd	ml/g	1.00	0.21	0.44

*STP = Standard Temperature and Presure; 1 atm, 25 ^oC

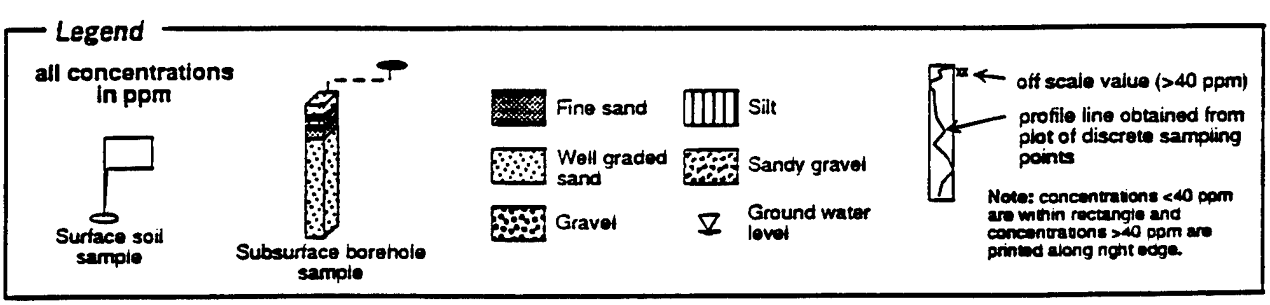
Nature & Extent of Contamination

- Elevated levels (>100 ppm) of contaminants limited to soils in the first 2 to 4 feet below the surface of the lagoons.
- Detectable concentrations found down to the ground water table due to vertical migration in highly permeable soils.
- Contaminant distribution varies versus depth and among borings indicating influence of microlithology.
- Concentrations for all explosives outside the lagoons were significantly lower than beneath the lagoons as lateral migration did not appear significant.
- Little correlation found between soil and ground water contaminant concentrations.

Soil Sampling Results: Contaminant Locations and Geologic Profiles



NOTE: *Additional surface and borehole sampling outside of the lagoons revealed significantly lower levels of contamination. Site ID numbers refer to borehole identification numbers used in site documentation.*



Site Conditions

- Surrounding region characterized by a semi-arid, cold desert climate
- Surrounding land use is primarily irrigated agriculture.
- The six foot deep lagoons were constructed with relatively permeable gravels.
- Soil beneath the lagoons is clean fine sand with gravel in the top 5 to 7 feet and predominantly sand below 25 to 35 feet; sand varies in character; gravel is fine grained with 1/4 to 1/2 inch particles; minor amounts of silt encountered as thin 1 to 24 inch seams.

Ground water levels vary between 44 to 49 feet below the bottom of the lagoons.

Key Soil Characteristics

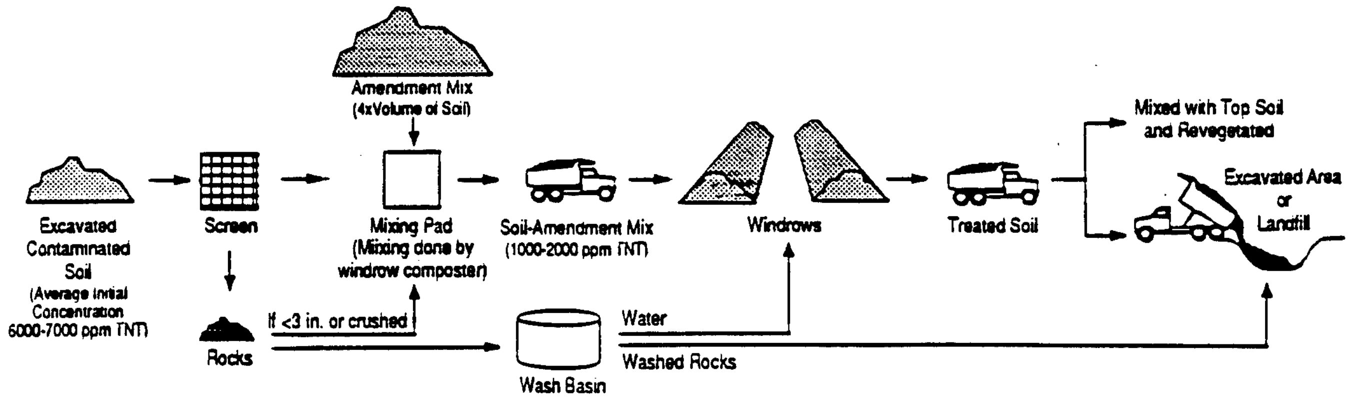
Parameter	Depth 0 ft	4 ft	10 ft	Comment *(all data taken from four soil borings beneath lagoons)*
pH	7.6-8.4	7.9-8.4	8.1-8.3	Relatively uniform and typical of mineral soils in arid regions
Moisture Content [%]	3.5-5.3	4.8-17.5	4.7-16.7	Higher for silt lenses; mean value of 7.2
Total Organic Content [%]	0.9-7.3	1.2-3.6	0.8-2.2	Corresponds with level of explosives contamination; mean value of 2.6

Site soils are predominantly Quincy fine sand and Quincy loamy fine sand:

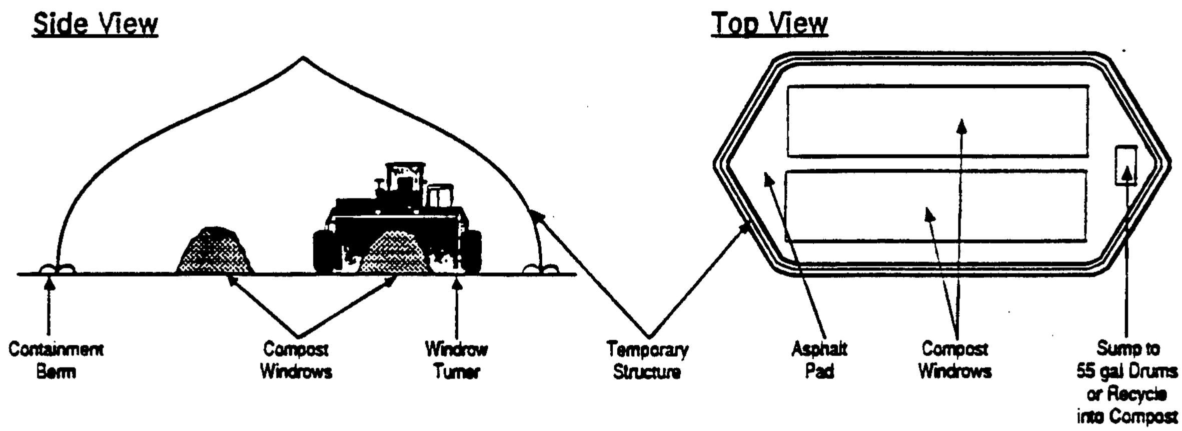
- **Quincy fine sand** is a very deep, excessively drained soil formed in mixed sand. Permeability is rapid and water-holding capacity is low. Effective rooting depth is greater than 5 feet. However, 80 percent of roots are found in the upper 12 inches. Soil pH gradually increases with depth from about neutral to 8.5 at 5 feet. Nearly 100 percent of the upper layer passes the 40 mesh sieve and about 30 percent passes the 200 mesh sieve. Wind erodibility is extremely high if vegetation is removed, which is the case at portions of Umatilla. Organic matter is generally less than 0.5 percent.
- **Quincy loamy fine sand** is very similar but occurs on slightly flatter slopes and has slightly more silt and clay in the upper layer, resulting in a higher water holding capacity.

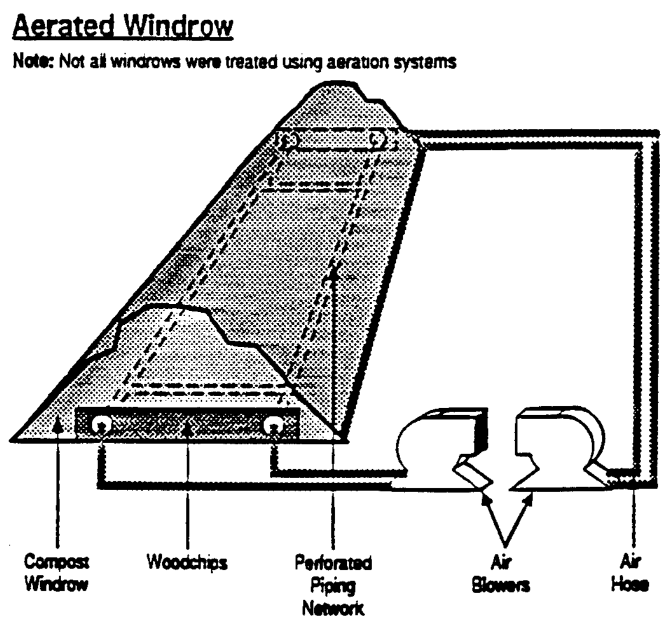
TREATMENT SYSTEM

Overall Process Schematic



Compost System Close-up





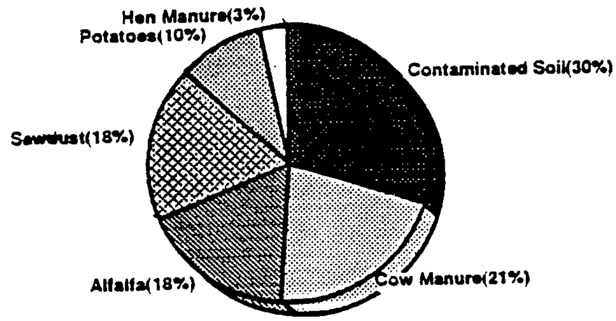
Compost Composition

The compost amendment recipe was developed through bench-scale treatability studies.

Factors taken into consideration included:

- carbon:nitrogen ratio
- moisture content
- homogeneity
- seasonal availability
- total metabolic energy content
- rate of carbon substrate use
- pH
- cost
- texture
- form
- porosity

The recipe utilized in windrows with a 30% soil loading rate was approximately:



Key Monitored Operating Parameters

Parameter	Range of Values*	Method of Control
Mixing Frequency	3 to 7 times/week	Frequency of windrow turner operation
Temperature	15 to 60°C	*Unaerated Windrows* - No control other than effects of mixing *Aerated Windrows* - Aeration blowers set to cool to set point of 55°C whenever 60°C was exceeded
Oxygen	≈0 to 21% O_2	*Unaerated Windrows* - No control other than effects of mixing *Aerated Windrows* - Aeration blowers set on an operating cycle of 15 minutes off/20 seconds on in addition to temperature control
Moisture	30 to 40%	Garden hose water addition used to maintain a 50 to 80% Water Holding Capacity (WHC) level
pH	5 to 9	Controlled through selection of compost amendment composition

* *Range of values observed during composting of contaminated windrows*
** *Temperature used as primary indicator of composting activity*

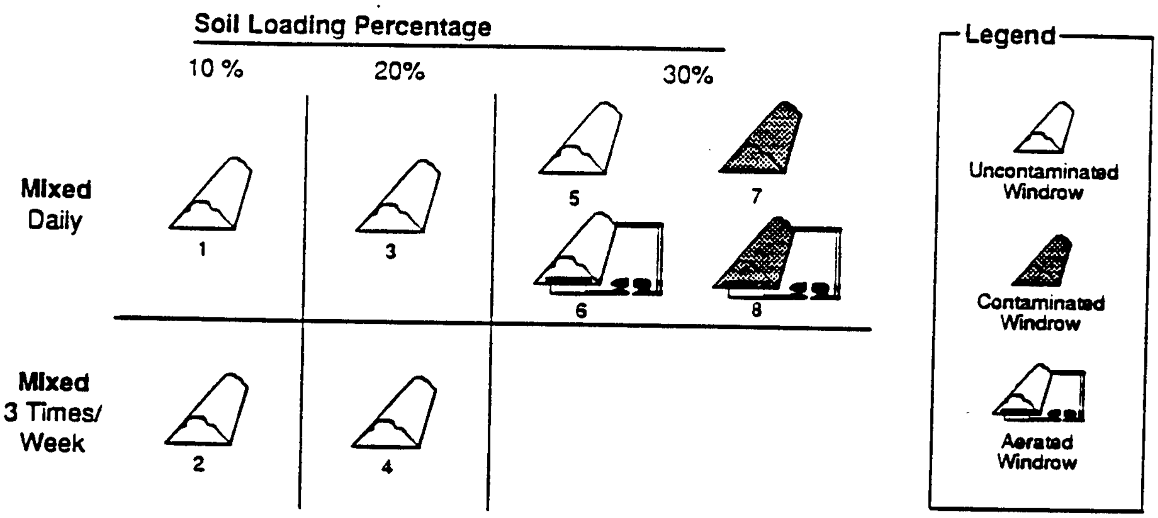
PERFORMANCE

Performance Objectives

- Achieve cleanup goal of 30 ppm TNT and RDX in top 5 feet of lagoon soils..
- Achieve optimum mixing frequency, soil loading rates, and degree of aeration during treatment.
- Determine potential treatment benefits from adding fresh amendment to active compost windrows *(supplementation)* and initiating new windows with active compost from existing windrows *(seeding)*.

Treatment Plan

A total of 6 uncontaminated and 2 contaminated windrows approximately 28 yd^3 in size were composted for 40 days either with or without aeration and with varying degrees of mixing and soil loading:



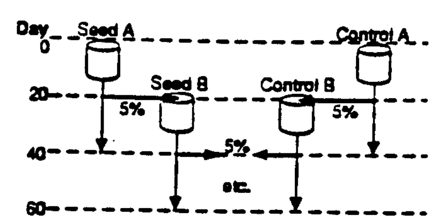
Initial Process Optimization Efforts

Uncontaminated Windrow Treatment

- Successful thermophilic composting observed in windrows with soil loading up to 30%.
- Aeration resulted in temporary overheating and a more rapid, but less prolonged, heating and composting for the blower configuration utilized.
- Windrow temperature increased and interstitial oxygen levels decreased to previous levels quickly (within an hour) following the temporary upset (temperature decrease and oxygen level increase) of mixing ---- Daily mixing frequencies were assumed to be appropriate for future treatments.
- Supplementation of active windrows through the addition of fresh amendment (5% by volume) resulted in rapid return of higher temperature levels indicating the potential to exceed the normal period of active thermophilic composting.

Seeding Results

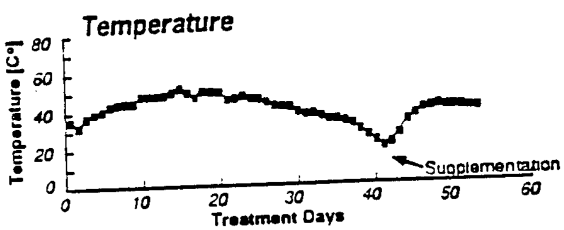
The effects of a 5% recycle from active to initiating piles was conducted in a series of 40 day runs in 50 gallon insulated, aerated, fiberglass tanks:

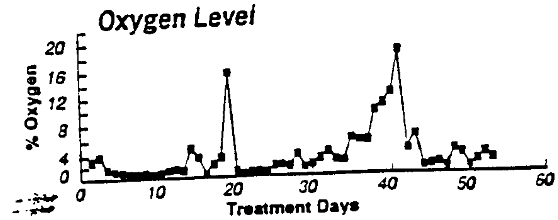


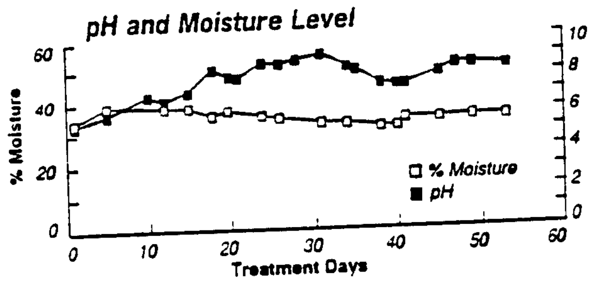
Based upon theoretical principles, the seeding approach should have illustrated some benefits. However, no concrete evidence of benefits was discovered in this study under the conditions tested.

Contaminated Windrow Treatment

Key Measured Parameters

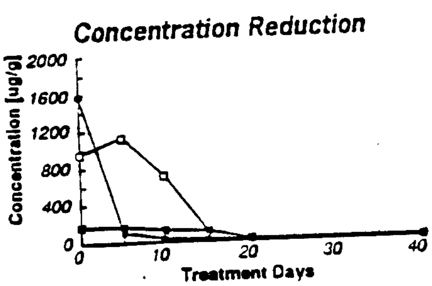


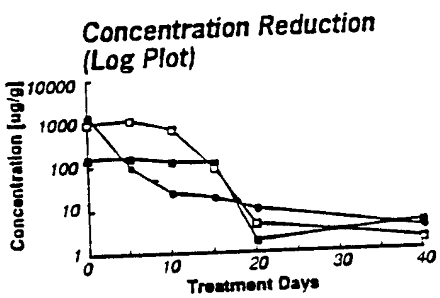


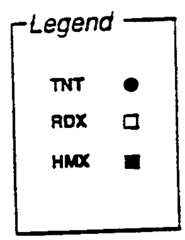


Note: All data provided for nonaerated windrow at times immediately before mixing by windrow turner. Aerated windrow data differed primarily by having oxygen levels in the 10 to 20% range during periods of high composting activity

Contaminant Removal Effectiveness







Aerated versus Nonaerated Windrow Performance

	Percent Removal		Concentration After 40 Day Treatment	
	Aerated	Nonaerated	Aerated	Nonaerated
TNT	99.8%	99.7%	4 ppm	4 ppm
RDX	99.2%	99.8%	7 ppm	2 ppm
HMX	76.6%	96.8%	47 ppm	5 ppm

Testing of Treated Product

- **Explosives Intermediates Analysis** - Likely intermediate products (2,4D-6NT; 4A-2,6DNT; 2,6D-4NT, and 2A-4,6DNT) were shown to be effectively removed (<5 ug/g after 40 days).
- **Clean Closure Leaching Test (CCLT)** - leachable explosives were removed after 40 days to a high degree (>99.6% removal for TNT, >98.6 for RDX, and >97.3 for HMX in the nonaerated windrow).
- **Leachate Toxicity Testing** - complete detoxification observed using ceriodaphnia dubia as a test organism.
- **Extractable Mutagenicity Testing** - toxicity reduction reduced during composting as measured through Ames assay.
- **Oversized Rock Washing** - Preliminary rock washing tests indicated that further development of techniques would be necessary to achieve cleanup criteria. However, other investigations have revealed that cleanup criteria can be achieved by composting small (<3 in.) rocks with soil. Minor modifications to the windrow composter will be made to implement this method during full-scale remediation at Umatilla.

COST

The UMDA windrow composting demonstration summarized in this analysis contained enhanced levels of analytical sampling as well as peripheral investigations. A cost estimate was developed to be representative of full-scale windrow composting at UMDA. The estimate (+30% to -15% accuracy) was based upon cost data from the demonstration and assumed:

- 20,000 tons of soil composted in a
- 5 year total project time with
- unaerated windrows, mixed daily, containing a
- 30% soil loading and composted for
- 30 day treatment periods with
- RCRA Waste Pile facility standards in effect.

Capital Costs

Equipment (Backhoe, Dump Truck, Front-End Loader, Water Pump, Windrow Turner)	$567,000
Site Work	280,000
Buildings/Structures	322,000
Mechanical/Piping	26,000
Electrical	129,000
Construction/Mobilization/Demobilization @ 8%	111,000
Construction Equipment, Consumables @ 5%	69,000
Fees @ 1.5%	20,000
General & Administrative Overhead Costs @ 9.5%	150,000
Contractor Markup and Profit @ 10%	168,000
Contingency @ 15%	276,000
Total	**$2,118,000**

Operating Costs

Power (@ $0.07/Kwhr)	$1,000
Amendments (@ $50/ton)	195,000
Diesel Fuel (@ $1.10/gal)	19,000
Labor (@ $20/hr Operator; $16/hr Technician excluding overhead)	116,000
Off-site Analytics ($220/sample)	21,000
Maintenance	64,000
Contractor Markup & Profit @ 10%	42,000
Contingency @ 15%	69,000
Total Annual Operating Cost	**$527,000**
Total 5-Year Present Worth Operating Cost	**$2,104,000**

Cost/Ton $211

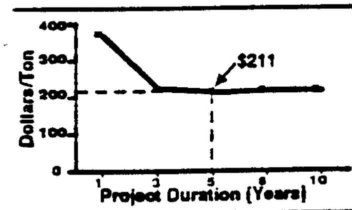
Cost Sensitivities

Effects of Assumption Changes

The $211/ton estimated cost is subject to the following sensitivities:

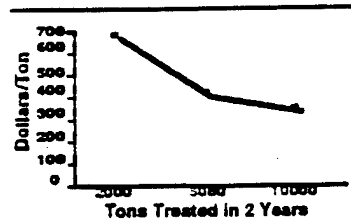
Accounting for salvage value of equipment following treatment	-$12
Elimination of RCRA Waste Pile facility requirements (liner system)	-$5
Elimination of temporary structure in mild climates	-$10 to -15
With a 40% rather than 30% soil loading rate	-$5 to -6
With 20 day rather than 30 day windrow compost periods	-$5
With 3 times/week rather than daily mixing of compost with turner	-$1

Cost versus Cleanup Time



Cost versus Facility Size

(for a 2-year project duration)



REGULATORY/INSTITUTIONAL ISSUES

- The explosives contaminated washout water sent to the lagoons is a listed RCRA waste. The compost windrows may be classified as waste piles under RCRA and therefore be subject to the facility design requirements of 40 CFR 264 Subpart L which include liners and leak detection systems. At UMDA these standards were not determined to be applicable because of the low reactivity hazard (explosive levels <12%) and low concentrations of 2,4-DNT (a listed RCRA waste), however, EPA Regional Administrators may make alternative determinations at other sites.

- An Army Explosives Hazard Review must be performed for work involving explosives. The hazard review of the compost turner determined that soils containing greater than 10% explosives by weight or chunks of explosives greater than 1 inch in diameter must be avoided.

- Windrow composting was the technology selected for overall clean-up of the CERCLA site in the Record of Decision. It was the preferred alternative to incineration and other composting schemes. The rural local community preferred composting not only because of apprehensions about incineration but also for the economic benefits the purchase of amendment materials would have for local farmers.

- Level C personal protective equipment was used for handling contaminated soils.

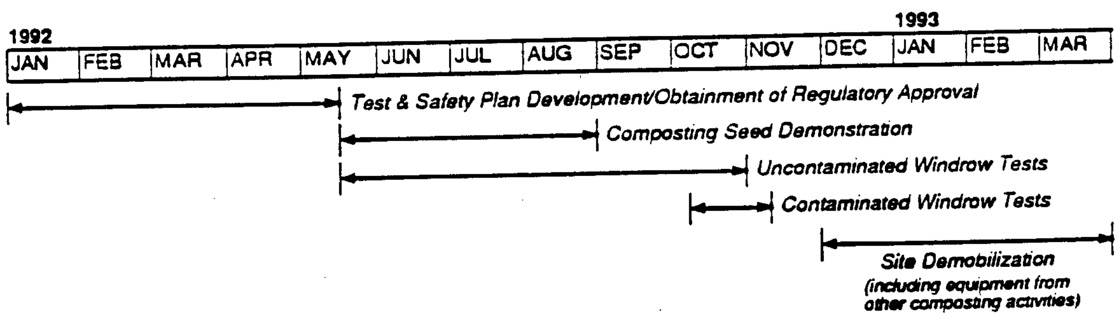
Cleanup Criteria

- Concentrations of explosives in soil must be below 30 ppm (TNT and RDX listed as target compounds).

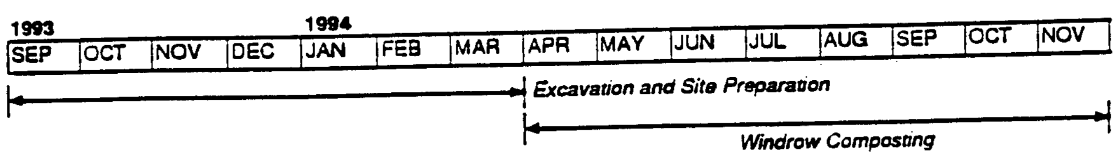
- The top five feet of soil below the lagoons is to be excavated, treated, and returned to the excavated area.

SCHEDULE

For Demonstration Activities at UMDA



Projection for Full-Scale Cleanup at UMDA



LESSONS LEARNED

Key Operating Parameters

- **Amendment composition** affects the biodegradation rate of explosives.
- **Temperatures** appropriate for thermophilic organisms (50 to 60°C) enhance biodegradation.
- **Mixing** with a windrow turner leads to a more rapid and extensive degradation.
- **Moisture content** should remain near 60%of the Water Holding Capacity.
- **Aeration** of windrows produced higher operating temperatures and reduced odor, however, the nonaerated windrows exhibited equal, or better, removal of TNT, RDX, and HMX.
- A **soil loading** rate of up to 30% soil in the soil-amendment mix produced satisfactory results.
- A **treatment period** of 40 days was sufficient to remove greater than 99% of TNT and RDX and leave residual levels of contamination less than 30 ppm. A composting period of 30 days was determined to be adequate for future composting at UMDA.
- **Oxygen** depletion in the unaerated windrows was found to occur soon after mixing (within an hour) and a daily turning frequency was adopted for future treatment.
- **Seeding** the initial mix of aerated static pile reactor compost piles with active compost from ongoing piles did not reveal any clear benefits under the conditions studies.
- **Supplementation** of fresh amendment to active compost windrows illustrated the potential to exceed the normal period of active thermophilic composting.

Implementation Considerations

- During composting inside the temporary structure, **release of water** vapor from the compost during turning reduced visibility. Accumulations of ammonia were also noted. Additional exhaust fans, personal protective equipment and modified operating procedures were used as remedial measures. Full-scale ventilation requirements should be evaluated for future applications.
- Additional effort was required to maintain the shape and configuration of the windrows. A small front end loader was found to be suitable for this purpose. **Maintenance of the windrows** was further complicated for windrows which had aeration systems.
- **Water supply** requirements must be considered in advance. Substantial quantities of water may be required to replace moisture lost during the composting process and to maintain adequate moisture levels. Several thousand gallons of water were used per windrow at UMDA.
- A **commercially available windrow turner** performed well mechanically and provided good results in composting operations. Some modifications may be useful to optimize performance such as variable mixer speeds, exhaust filtration, and the addition of deflectors to minimize the potential for projectiles such as small stone to be thrown during turning.
- **Field instrumentation** employed was suitable for monitoring the composting process. Less intensive monitoring than was employed in this demonstration would be more appropriate for future applications.
- Improvements in **compost sample preparation and analysis protocols** would be beneficial. Field analytical methods for explosives in compost would be useful in process monitoring, with laboratory analyses used for confirmation of cleanup criteria. Modifying the compost sample preparation procedure to minimize drying time would speed operations.
- The windrow composting treatment was successfully conducted under a wide range of **ambient temperatures.** Thermophilic conditions were attained during summer months when daytime highs were well above 100°F, as well as during late autumn when nighttime lows dropped below freezing. From these observations, it appears that with proper containment within an enclosure and with slight adjustments to turning frequency to control heat losses from the material, windrow composting can be implemented year round.

Technology Limitations

• Although detailed projections of costs have been made based upon the results of demonstration activities at UMDA, there is a **lack of cost data** from full-scale completed remediations.

• The **cost of the technology is sensitive** to the availability and cost of amendment material, cleanup criteria for a given site, and the treatment facility standards deemed applicable to the composting operation.

• The presence of other contaminants such as **metals may preclude the use of the technology** for some sites with explosives-contaminated soils.

• **Areas for further progress** include efforts to increase compost soil loading percentages, decrease compost cycle times, and improve methods to treat oversized rocks screened from the compost windrows.

Future Technology Selection Considerations

• The **treatment at UMDA built upon earlier results** from studies which illustrated the susceptibility of explosives to microbial degradation, the effectiveness of mechanically agitated in-vessel and aerated static pile composting systems, and the influence of process parameters such as soil loading percentage and compost amendment composition.

• The **treatment at UMDA further demonstrated** that windrow composting of explosives contaminated soil:

+ will effectively **remove** both **explosives** (TNT, RDX, and HMX) and selected TNT intermediates,
+ will **reduce toxicity** to a high degree,
+ is relatively **simple** to implement and operate, and
+ is **cost effective** in relation to alternative treatments.

ANALYSIS PREPARATION

This analysis was prepared by:

Stone & Webster Environmental
Technology & Services

245 Summer Street
Boston, MA 02210
Contact: Bruno Brodfeld (617) 589-2767

CERTIFICATION

This analysis accurately reflects the performance and costs of the remediation:

X ____________	X ____________	X ____________
NAME HERE Remedial Project Manager Umatilla Army Depot Activity	NAME HERE Department of Environmental Quality State of Oregon	NAME HERE Remedial Project Manager U.S. Environmental Protection Agency Region X

SOURCES

Major Sources For Each Section

Site Characteristics:	Source #s (from list below) 5,6,8 and 9
Treatment System:	Source #s 1,2 and 7
Performance:	Source #s 1 and 2
Cost:	Source # 1
Regulatory/Institutional Issues:	Source #s 1,2,5,9,12 and personal communication with Capt. Kevin Keehan, U.S. Army Environmental Center (410) 671-1228.
Schedule:	Personal communication with Capt. Timothy O'Rourke, U.S. Army Environmental Center, (410) 671-1580.
Lessons Learned:	Source #s 1,2,5,7, 9, 11, 12 and personal communications with Capt. Keehan.

Chronological List of Sources and Additional References

1. *Windrow Composting Engineering/Economic Evaluation*, CETHA-TS-CR-93050, prepared for U.S. Army Environmental Center, prepared by Roy F. Weston, Inc., May 1993.

2. *Windrow Composting Demonstration for Explosives-Contaminated Soils at Umatilla Depot Activity, Hermiston, Oregon*, CETHA-TS-CR-93043, prepared for U.S. Army Environmental Center, prepared by Roy F. Weston, Inc., April 1993.

3. *Composting of Explosives-Contaminated Soil at the U.S. Army Umatilla Depot Activity*, prepared by U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), presented at the EPA Forum on Innovative Treatment Technologies, San Francisco, CA, November 1992.

4. *The Preparation and Analysis of Soil Compost Material for Inorganic and Explosive Constituents*, CETHA-TS-CR-92067, prepared for USATHAMA, prepared by U.S. Geological Survey, October 1992.

5. *Feasibility Study for the Explosives Washout Lagoons (Site 4) Soils Operable Unit Umatilla Depot Activity (UMDA) Hermiston, Oregon*, CETHA-TS-CR-92017, prepared for USATHAMA, prepared by CH2M Hill and Morrison Knudsen Environmental Services, April 1992.

6. *Explosives Washout Lagoons Soils Operable Unit Supplemental Investigation Technical and Environmental Management Support of Installation Restoration Technology Development Program Umatilla Depot Activity Hermiston, Oregon*, CETHA-BC-CR-92016, prepared for USATHAMA, prepared by Morrison Knudsen Environmental Services and CH2M Hill, April 1992.

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