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Abstract. In the 1970s and 1980s, efforts to manage mixed waste and reduce pollution focused largely on post-process measures. In the late 1980s, the approach to waste management and pollution control changed, focusing on minimization and prevention rather than abatement, treatment, and disposal. The new approach, and the formulated guidance from the U.S. Department of Energy, was to take all necessary measures to minimize waste and prevent the release of pollutants to the environment. Two measures emphasized in particular were source reduction (reducing the volume and toxicity of the waste source) and recycling.

In 1988, a waste minimization and pollution prevention program was initiated at Site 300, where the Lawrence Livermore National Laboratory (LLNL) conducts explosives testing. LLNL's Defense Systems/Nuclear Design (DS/ND) Program has adopted a variety of conservation techniques to minimize waste generation and cut disposal costs associated with ongoing operations. The techniques include minimizing the generation of depleted uranium and lead mixed waste through inventory control and material substitution measures and through developing a management system to recycle surplus explosives. The changes implemented have reduced annual mixed waste volumes by more than 95% and reduced overall radioactive waste generation (low-level and mixed) by more than 75%. The measures employed were cost-effective and easily implemented.

BACKGROUND

LLNL Defense Systems Program research is conducted at Site 300. At the Site 300 firing facilities, we burn or detonate non-nuclear weapons components and materials to verify weapons design and material performance. Prior to 1989, virtually all of the waste generated at the explosive testing facilities, which amounted to approximately 500,000 kg annually, was characterized as mixed waste. Our mixed waste was disposed of in on-site landfills, which were regulated as interim status Resource Conservation and Recovery Act (RCRA) land disposal units. In November 1988, this practice was terminated. LLNL management determined that land disposal of our explosive testing facilities' untreated mixed waste was not practicable nor desirable from a compliance perspective. We substituted mixed waste land disposal practices with a commitment to waste minimization, which meant avoiding or reducing the volume of mixed waste generated, and establishing a program to meet the commitment.

PROGRAM ORGANIZATION AND GOALS

In establishing our waste minimization program, we developed an organizational structure for managing and implementing our waste minimization efforts. We defined the roles and responsibilities of those involved, and the policies and goals to be instituted. Our management (Defense Systems Program) assigned line responsibility for the development and implementation of the changes to the management of the explosives testing facility. DS management believed that the explosives testing employees, who are familiar with the materials, processes, and procedures for the operations, were the best resources for identifying areas where waste minimization changes could be made. The Defense Systems Program waste minimization organization is shown in Figure 1.

Our goal was to reduce the total volume of hazardous and mixed wastes by at least 25% in three to five years, using volumes generated in 1988 as our baseline. We achieved that goal one year later, in 1989, using the methods described below.

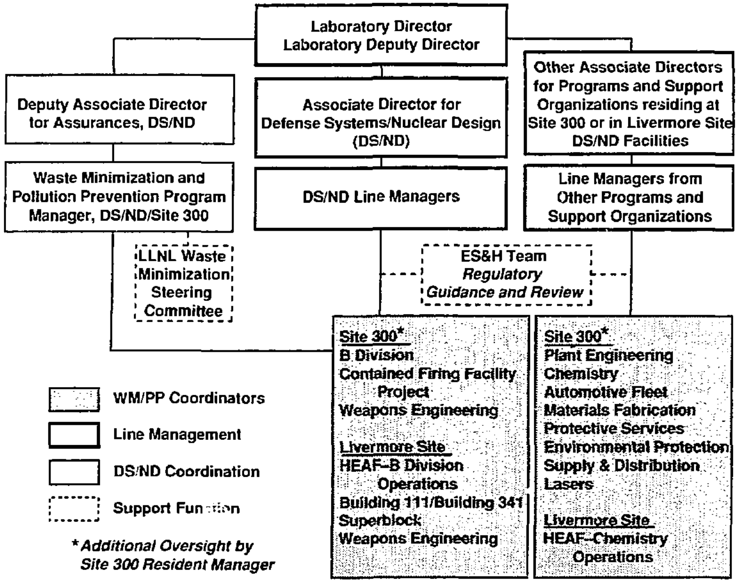

Figure 1. DS/ND WMPP Organization.

WASTE MINIMIZATION METHODS

The first step we took involved developing a detailed characterization of all the materials entering and exiting the explosive testing operation, and identifying all the materials control and waste generation points along the way. We identified five target areas where we believed there were opportunities for waste reduction:

- Several hazardous materials were potential components of experiments, and the various experimenters using them did not have a mechanism for formally declaring that the waste from their test was potentially mixed waste.
- Procedures were not in place to control materials present on the firing table prior to explosives testing and removal of waste materials for disposal.
- Lead used as weights and as shielding material in the operations was largely responsible for the creation of mixed waste from the operations.
- At the conclusion of a number of types of explosive tests, the remains of tents constructed with lumber and plastic were left in configurations that resulted in large volumes of waste with large void spaces.
- Virgin explosives were used for routine maintenance and training operations.

Utilizing this information, we adopted the following hierarchical approach: (1) eliminating or reducing sources of mixed waste by material, process, or housekeeping controls; (2) recycling wastes through reclamation or reuse; or (3) if these two options were not available, arranging for environmentally acceptable waste treatment to reduce the toxicity and/or volume of the mixed waste generated. We used source reduction methods to address the five waste minimization target areas identified below. The specific changes we made in inventory control, explosive test procedures, management of lead, tent construction, and reuse of explosives are described in detail below.

Inventory Control

All Site 300 explosives testing activities are required to have a formal "peer review" accompanied by a completed data base form that describes materials to be used in the test. This data base form, shown in Figure 2, specifically highlights state and federal hazardous constituents which could, if present, cause the waste to be a mixed waste instead of a low-level waste. The data base form has two columns: one column is filled out by the lead experimenter, and the other is filled out by the facility supervisor or designee. The combined information represents the potential wastes to be generated from the experiment.

Completion of this form before the test encourages one of two results: (1) either non-hazardous constituents are substituted for hazardous constituents or (2) plans are developed to ensure that the waste from the experiment is segregated from other non-mixed waste and is strictly managed as potential mixed waste. This new inventory control process prevents inadvertent hazardous material from entering the wastestream.

Explosives Test Procedures

A detailed procedure was written as a reference and training guide for employees involved in the explosive testing operations. The procedure describes potential wastestreams; the steps to be followed in removing, packaging, storing, and managing the waste; and training requirements for handling the waste. The procedure also contains information to prevent removal of excessive amounts of firing table gravel following an experiment.

Management of Lead

We dramatically minimized the generation of depleted uranium and lead mixed waste at the explosive test facilities by (1) substituting nonhazardous steel weights for lead weights in all operations and (2) using aluminum or steel barriers to protect lead shielding from fragmentation. Implementation of these simple, cost-effective measures resulted in savings of approximately $500K after the first year of implementation.

Tent Construction

The design of the tents used to enclose explosives tests was changed from a plastic and lumber tent that generated a large volume, twisted mass to a cloth tent supported by ropes that collapsed into a much smaller volume of waste following testing. Implementation of this measure saved approximately $50K in 1990.

Explosives Reuse

Surplus explosives pieces from other LLNL explosives operations are used in place of new stock explosives for shot evaluations, microbarograph testing, and employee training exercises. A user-friendly on-line computer data base was developed by LLNL to facilitate the use of surplus explosives. Users can advertise the availability of surplus explosives, locate sources of needed explosives, and post notices for explosives that are being sought. The surplus explosives are made available to experimenters at no cost. Figure 3 illustrates the types of information provided to users of the data base. The surplus explosives data base system promotes minimization of reactive wastes.

PLEASE enter weights or volumes in the units called for.

B-DIVISION SITE 300 SHOT DATABASE INFORMATION

>> RAMRODS/EXPERIMENTERS: List ONLY materials in the shot assembly that will end up in the bunker waste stream.
DO NOT include material that will be recovered or recycled.

>> BUNKER: List ONLY the bunker-placed materials that will end up in the bunker waste stream.
DO NOT include material that will be recovered or recycled.

>> If this completed form is UNCLASSIFIED, submit it with the Pre-Shot.
If this completed form is CLASSIFIED, submit it appropriately as a Classified Work Paper to Alberta Tracy, L-801

>> NOTE: Bunker Supervisors MUST be notified well in advance of any experiment containing any materials listed below that are preceded by a bullet (•).

No.	Item	Units	RAMROD	BUNKER
	Type of experiment* * *			XXXXXXXX
	Account #			XXXXXXXX
	Bunker Shot #		XXXXXXXX	
	Shot Name			XXXXXXXX
	Fire Date		XXXXXXXX	
	Ramrod			XXXXXXXX
	Diagnostics >>>>>>			
	Program			XXXXXXXX
	Explosive #1 (name)*	XXX		
	Explosive #1 (wt.)	(Kg)		
	Explosive #2 (name)*	XXX		
	Explosive #2 (wt.)	(Kg)		
	Explosive #3 (name)*	XXX		
	Explosive #3 (wt.)	(Kg)		
	Explosive #4 (name)*	XXX		
	Explosive #4 (wt.)	(Kg)		
1	Antimony* *	(gm)		
2	Arsenic* *	(gm)		
3	Asbestos	(gm)		
4	(•) Barium* *	(gm)		
5	Beryllium* *	(gm)		
6	(•) Cadmium* *	(gm)		
7	(•) Chromium IV* *	(gm)		
8	(•) Chromium III* *	(gm)		
9	Cobalt* *	(gm)		
10	Copper* *	(gm)		
11	Flouride Salts	(gm)		
12	(•) Lead* *	(gm)		
13	(•) Mercury* *	(gm)		
14	Molybdenum* *	(gm)		
15	Nickel* *	(gm)		
16	(•) Selenium* *	(gm)		
17	(•) Silver* *	(gm)		
18	Thallium* *	(gm)		
19	Vanadium* *	(gm)		
20	Zinc* *	(gm)		
21	Other lithium salt compounds	(gm)		
22	Tritium (in micrograms)	(ugm)		
23	Thorium* *	(gm)		
24	Uranium* *	(gm)		
25	Corrosives (eg.: acids, bases)	(ml)		
26	Solvents	(ml)		
27	PCB	(ml)		
	Comment(s)			
	Comment(s)			

* (i.e., LX-10, 9404, Comp-B, propellant, etc.)
* * (and/or compounds)

*** * * Expmt type (choose one)**
- Conventional weapons
- Device hydro
- Diagnostic development
- Environmental
- HE development
- Proliferation/NEST
- SDI
- Structural studies
- Surety
- Other (define)

<< DIAGNOSTICS	
450 X-Ray	X
Accelerometers	ACC
Digitizers	D
Effects	E
Fabry-Perot	I
Flashlamps	FL
FXR	F
Hycam	HC
IC Camera	IC
Laser Fid	LF
Linac	L
Locam	LC
Optics	O
Pins	P
Recovery	R
Scopes	S
Strain Gauges	SG
Thermocouple	T
Video	V

Ramrod name (please print):

Ramrod signature:

Bunker Rep name (please print):

Bunker Rep signature:

Waste Certification Program:
Print name: ______ Signature: ______
Date: ______

NOTE: Before table gravel from this shot is loaded into boxes, this sheet must be reviewed and signed by the LLNL Waste Certification Officer or designee.
This signature certifies that the container contents are as reported on this form

April 93 issue. Discontinue use of earlier issues.

Figure 2. B-Division Site 300 Shot Database Information waste certification form.

Explosives Inventory Data ID#: ____________

Explosive Name: ____________
Composition: ____________ Quantity: ________ ○gms ○lbs ○kgs
Form: ○*bulk powder* ○*pressed* ○*cast/cured* ○*paste* ○*liquid*
Storage Review Date: ____________ DOT Shipping Class: ____________
Classification (new UN designation, if available): ____________
Container: ○*plastic* ○*glass* ○*cardboard* ○*other (specify)* ____________
Contact: ○*Livermore Site* ○*Site 300*
Name: ____________ Phone: ________ FAX: ________ L-Code: ______
Description/Special Release Requirements:

____

____

Entry Date: ____________

Assure LLNL requirements are met before and during material transfer. Custodianship is transferred with material. Upon completion of exchange, send message to System Operator.

Figure 3. Explosives Inventory Data Base entry form.

ACCOMPLISHMENTS

When we started our waste minimization program in 1988, our goal was to achieve a 25% reduction in waste volumes within three to five years. We accomplished this one year later, in 1989. Since then, continual improvements have been made to reduce the volume of our explosives testing operations wastestream. As a result of the measures described above, we have reduced the estimated 484,000 kg of mixed waste generated in 1988 to approximately

263,000 kg of low level waste in 1989
141,000 kg of low level waste in 1990
115,000 kg of low level waste in 1991, and finally
72,500 kg of low level waste in 1992.

This represents an 85% reduction in the mixed waste stream since 1989. Throughout this period, the number of explosives tests remained constant, so the reduction cannot be attributed to reduced activity. The results of our efforts are shown in Figure 4. As of the end of calendar year 1992, approximately $1.6M in mixed waste container purchase, transport, and disposal costs have been avoided as a result of our efforts.

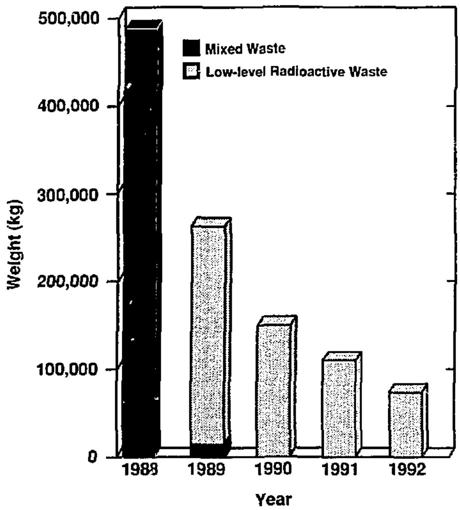

Figure 4. Fi.. ˙ table gravel and debris: waste generated 1988–1992.

FUTURE ACTIVITIES

Plans are underway to examine the feasibility of recycling the gravel component of the wastestream. The gravel component represents approximately 15% of the wastestream. In our new study, we will determine whether it is cost beneficial to sieve, wash, and recycle the gravel and to recycle the water used in the process. This study is planned for late 1993.

ACKNOWLEDGMENTS

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