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Project Summary

Waste Minimization Opportunity Assessment: Philadelphia Naval Shipyard

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The Waste Reduction Evaluation at Federal Sites (WREAFS) Program consists of a series of demonstration and evaluation projects for waste reduction conducted cooperatively by the U.S. Environmental Protection Agency (EPA) and various parts of other federal agencies. The objectives of the WREAFS Program include: (1) conducting waste minimization (WM) workshops; (2) performing WM opportunity assessments; (3) demonstrating WM techniques or technologies at federal facilities; and (4) enhancing WM benefits within the federal community.

An assessment was made of several operations at the Philadelphia Naval Shipyard (PNSY), a federal facility which specializes in revitalizing and repairing ships already in fleet. A wide range of industrial processes are done at the PNSY, and many of them generate wastes. This project focused on the processes and wastes of operations related to aluminum cleaning, spray painting, and bilge cleaning. Seven WM options were evaluated during this project with the use of EPA's *Waste Minimization Opportunity Assessment Manual.**

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Purpose of the Project

The purpose of this project was to develop WM plans for the PNSY with the use of EPA's Waste Minimization Opportunity Assessment Manual. This manual provides a systematic, planned procedure for identifying ways to reduce or eliminate waste. The project was conducted in cooperation with PNSY's Environmental Safety and Health Office. The Shipyard has an ongoing program for WM. With their guidance, several industrial operations were selected for application of the new WM procedures. Results from this project will be used as a guidance tool for evaluating WM opportunities at their other industrial activities, particularly at facilities operating aqueous cleaning and spray painting processes. The procedures employed to identify and evaluate WM alternatives are, however, applicable to most industrial operations.

The Waste Minimization Assessment Procedure

The WM assessment procedures consist of four major steps (Figure 1). This project completed the first three steps of the procedures for several selected industrial activities.

The *WM Manual* contains a set of 19 worksheets which are designed to facilitate the WM assessment procedure (Table 1). Worksheets 2 through 16 were completed for the assigned areas during this project.

The following three industrial areas at the PNSY were selected for evaluation during

*Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003), Hazardous Waste Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, 1988.

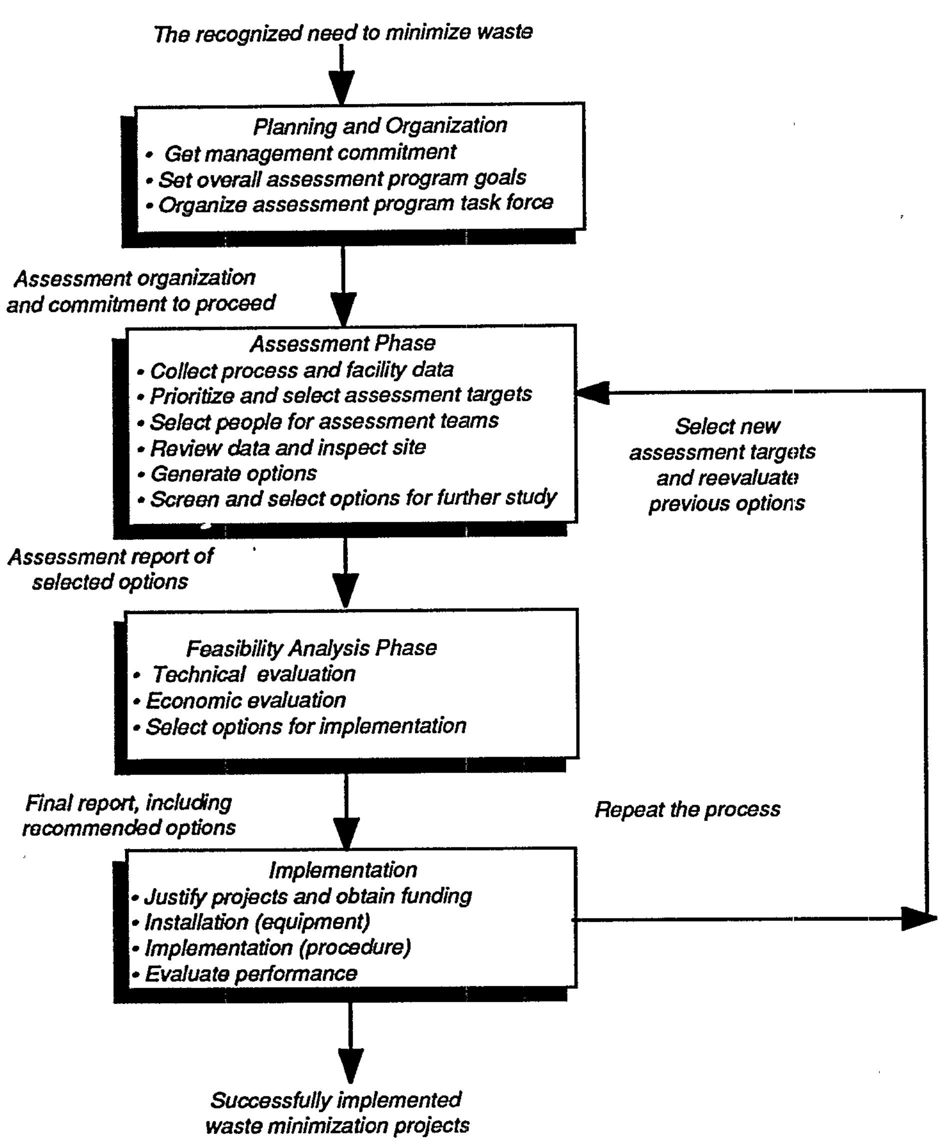

Figure 1. The waste minimization assessment procedure.

this project: Building 990 - aluminum cleaning and spray painting; Building 1028 - spray painting of steel parts including structural columns; and citric acid bilge cleaning operations conducted in drydock.

A 3-day assessment phase survey focused on collecting process and waste data and identifying procedures for waste management. Many sections for Worksheets 2 through 9 were completed at this time. After completing the survey, additional data and information were collected and verified; the assessment and feasibility analyses phases of the WM assessment (Worksheets 10 through 16) were then completed.

Description of Areas Selected for WM Assessment

The PNSY generates a wide range of wastes. In terms of volume, the most significant wastes include alkaline liquid wastes, paint and paint products, and waste acid. The industrial activities selected for this project included those in Building 990 where aluminum products are fabricated and surface coated and those in Building 1028 where steel parts are spray painted. Also, included in the study was the citric acid derusting operation located at the drydocks.

Building 990

An aluminum cleaning operation is performed to remove oil and other materials from the surfaces of aluminum sheets before tungsten inert gas welding. This process is critical because the welding operations cannot be done unless the metal surfaces are properly cleaned. The cleaning line consists of two process tanks containing a proprietary cleaning solution and two rinse tanks containing tap water. One process tank is heated (steam coil) and the other is at ambient temperature; both rinse tanks are heated. The cleaning procedure consists of loading aluminum sheets into a metal basket, hoisting the basket into a process tank for 5 min, followed by rinsing in one of the rinse tanks.

The process tanks become diluted after repeated operation due to dragout losses and tap water replenishment. These tanks also collect floating oil, and the solution becomes contaminated with suspended solids. After approximately 3 mo operation, the process tanks are pumped to a tank truck and disposed of by a contractor.

The rinse tanks are operated as nonflowing rinses because of the low pH of the rinse water and the lack of neutralization facilities. The rinse tanks are disposed of in the same manner as the process tanks but more frequently, usually every 2 wk.

This project evaluated drag-out reduction methods and an alternative rinsing procedure that would reduce the frequency of discharge for these wastestreams.

Small and medium sized aluminum parts are spray painted in Building 990. Rags dipped into xylene are used to degrease the aluminum parts. The parts are then spray painted in a water curtain booth (which collects the paint overspray): typically, a zinc chromate primer, air drying, a final enamel paint coating, and air drying. A new booth water chemical system was used for the first time during the survey.

The new process consists of several steps. Initially, a booth-cleaning chemical (SW-3*) is used to remove overspray and paint sludge from the booth surfaces. These paint solids are removed and drummed, and the booth water is discharged to the sewer. This cleaning process will be scheduled every 6 mo. After cleaning, the booth is refilled with fresh water and a detackification chemical (Surround*) is added along with a

* Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Table 1. *List of Waste Minimization Assessment Worksheets*

Phase	*Number and Title*	*Purpose/Remarks*
	1. Assessment Overview	*Summarizes the overall assessment procedure.*
Step 1 - Planning and Organization	*2. Program Organization*	*Records key members in the WM assessment program task force and assessment teams. Also records the relevant organization.*
(Section 2)	*3. Assessment Team Make-up*	*Lists names of assessment team members as well as duties. Includes a list of potential departments to consider when selecting the teams.*
Step 2 - Assessment Phase	*4. Site Description*	*Lists background information about the facility, including location, products, and operations.*
	5. Personnel	*Records information about the personnel who work in the area to be assessed.*
	6. Process Information	*Provides a checklist of useful process information to look for before starting the assessment.*
	7. Input Materials Summary	*Records input material information for a specific production or process area. This includes name, supplier, hazardous component or properties, cost, delivery and shelf-life information, and possible substitutes.*
	8. Products Summary	*Identifies hazardous components, production rate, revenues, and other information about products.*
	9. Individual Waste Stream Characterization	*Records source, hazard, generation rate, disposal cost, and method of treatment or disposal for each waste stream.*
	10. Waste Stream Summary	*Summarizes all of the information collected for each waste stream. This sheet is also used to prioritize waste streams to assess.*
	11. Option Generation	*Records options proposed during brainstorming or nominal group technique sessions. Includes the rationale for proposing each option.*
	12. Option Description	*Describes and summarizes information about a proposed option. Also notes approval of promising options.*
	13. Options Evaluation by Weighted Sum Method	*Evaluates for screening options using the weighted sum method.*
Step 3 - Feasibility Analysis Phase	*14. Technical Feasibility*	*Provides detailed checklist for performing a technical evaluation of a WM option. This worksheet is divided into sections for equipment-related options, personnel/procedural-related options, and materials-related options.*
	15. Cost Information	*Provides detailed list of capital and operating cost information for use in the economic evaluation of an option.*
	16. Profitability Worksheet #1 Payback Period	*Calculates the payback period, based on the capital and operating cost information developed from Worksheet 15.*
	17. Profitability Worksheet #2 Cash Flow for NPV and IRR	*Develops cash flows for calculating net present value (NPV) or internal rate of return (IRR).*
Step 4 - Implementation	*18. Project Summary*	*Summarizes important tasks to be performed during the implementation of an option. This includes deliverable, responsible person, budget, and schedule.*
	19. Option Performance	*Records material balance information for evaluating the performance of an implemented option.*

buffer. Surround is an organic polymer that causes the paint overspray to form a fine colloidal precipitant, which is dispersed throughout the booth. The buffer maintains the optimal pH for precipitant formation. In this form, paint particles do not clog the booth's water recycle spray nozzles or piping system and tend not to adhere to booth surfaces. After operating approximately 2 wk, a second organic polymer (Unite*) is added; this coagulates the dispersed paint into a floating mass or sludge. This sludge is removed by screening and drummed for disposal. The booth water can be reused after adding more Surround. After approximately 6 mo, the system is cleaned using the SW-3 procedure.

The economics of the new booth maintenance system were evaluated during this project, and optional dewatering equipment, currently under consideration by PNSY, was evaluated. The dewatering equipment will reduce the volume of paint sludge generated by the maintenance system.

Building 1028

Steel parts and columns are spray painted at various areas in Building 1028: (1) a large, shot blasting/painting booth with a dry air filtration system, (2) a shape abraider/spray booth for blasting and painting steel columns, and (3) a water curtain booth. Each system is used for epoxy spray painting of steel surfaces. The water curtain booth consists of two large water curtains (each approximately 18 ft long), one of which was inoperable at the time of the survey. A booth water deflocculant, Booth Compound 702*, is employed for booth water maintenance. The new booth chemical system described for Building 990 is being considered for Building 1028. The economics of this application were evaluated during the project.

Citric Acid Bilge Cleaning

PNSY employs a citric-acid, chemical cleaning process for ships' tanks, bilges, and void spaces. It is generally done while ships are in drydock. This relatively new (1976) process replaces mechanical methods of cleaning and derusting metal surfaces. After a citric acid/triethanolamine (TEA) solution is used to remove the oxides from the metal surfaces, the surfaces are neutralized and rinsed with dilute solutions.

At PNSY, the citric acid process employs a treatment rig housed in a 40-ft trailer that is lowered into the drydock. The trailer contains the process solutions, pumps, and controls. To remove grease and oil from the metal surfaces inside the ship's bilges, a degreaser is applied using hand-held, garden-type sprayers. This solution is washed down with a high-pressure water spray. Then, existing paint is stripped. After a second rinse, a hot, concentrated citric acid/TEA solution (10% citric acid, 7% TEA) is applied with hydroblast (high pressure) guns to remove rust. The solution run-off is collected and pumped back to the rig for recycling. After treatment is complete, the solution is pumped to a waste container for disposal. Following derusting, a hot neutralizer (<1% citric acid, 4% TEA) is sprayed on the metal surfaces. Run-off is pumped to a waste tank. As a final rinse, a 1% TEA solution is sprayed on the steel surfaces. Any run-off is again pumped to a waste tank.

The volume of spent solutions from a derusting/neutralization/rinse operation is typically about 3,000 gal (1,000 gal of each solution). This solution generally has a pH below 4.0 and contains toxic metals. It is contractor hauled for treatment and disposal.

Waste Minimization Options

Option 1 - KRC-7X Dragout Reduction and Bath Maintenance

In Option 1, a hand-held spray rinse is applied over the process tanks. After impacting the basket and parts, the rinse water drips into the process tank. The spray rinse is expected to return 90% of the dragout back to the process tank. The amount of rinse water used depends on the evaporation rate of the process tanks, which is expected to be in the range of 4 to 8 gph per tank.

The acid baths accumulate oil from the parts and solids from the parts and surrounding air. Because dragout losses return to the process tanks, contaminants accumulate at a faster pace -- contaminants that may interfere with the cleaning process. A bath maintenance system is, therefore, recommended. This system includes an oil skimmer for floating oil and grease removal and a cartridge filter for suspended solids removal.

The dragout reduction and bath maintenance systems are expected to extend the usable life of the baths to 1 yr. Small additions of KRC-7X may be necessary to make up for dragout not returned to the bath.

Option 2 - KRC-7X Two-Stage Rinse

Rinsing is presently done in stagnant tanks that are pumped and contractor hauled every 2 wk. The proposed system would employ a two-stage rinse. From the right side of the line, the basket would exit the KRC-7X tank, be rinsed in Rinse #1, and then be rinsed in Rinse #2. After Rinse # 1 becomes contaminated, its contents would be disposed of and the tank would be refilled with water. The sequence of rinsing would then be changed. Rinse # 2 would serve as the initial rinse and Rinse #1 as the final rinse (i.e., the cleaner rinse would always be the final rinse).

Option 3 - Booth Guard System

The 3-phase Booth Guard System (a biannual cleaning, normal operation, and biweekly paint removal) is currently being tried in the Building 990 Paint Spray Booth. This option involves permanently adopting the process in Buildings 990 and 1028.

Although this option requires different raw materials and instruction of booth operators in their use, no new equipment is required. Savings will result from less downtime for the paint spray booth, less operator maintenance time for the booth, and less cleaning wear and tear on the booth.

Option 4 - Paint Sludge Dewatering

The paint spray booth generates a paint sludge that is disposed of as waste during routine maintenance -- paint sludge composed of a high percentage of water. If this water can be extracted and recycled to the booth, the volume of disposed of waste is decreased.

Paint sludge can be dewatered mechanically with the use of a bag filter, roll bed filter, filter press, or hydrocyclones. Here the quantity of sludge makes the hydrocyclone the most economical method of dewatering. Centrifugal force separates paint solids from the booth water, paint solids drop into a waste receptacle (bag or drum), and clear water is pumped back to the booth. The process is used continuously while the booth is in operation. When the volume of paint overspray is low, a single hydrocyclone could be moved (depending on the equipment selected) and used at other booths.

This option requires the purchase of the hydrocyclone unit and the piping to connect it to the paint spray booth. The unit would be turned on when the booth is started for the day and shut down at the end of the first shift, just before shutting down the paint spray booth. Routine maintenance requires removing the waste receptacle when it is full and lubricating moving parts within the unit. This option eliminates the need for the booth operator to manually remove paint booth sludge; the use of the chemical, Unite, as a flocculant; and downtime of the booth for biweekly cleaning.

Option 5 - High-Volume/Low-Pressure Painting

Currently, common, compressed-air-type equipment is used for spray painting in Buildings 990 and 1028. This type of spray painting has a relatively low transfer efficiency (i.e., the amount of the coating applied to the surface, divided by the amount of coating sprayed from the gun, expressed as a percentage).

A new paint spraying technique, which may be applicable to these operations is the high-volume/low-pressure (HVLP) method. The transfer efficiency of HVLP is between 65% and 90%; that of compressed air equipment, 25%. Other methods of spray painting such as airless, air-assisted airless, and electrostatic spray painting have transfer efficiencies from 35% to 65%, with electrostatic spray painting having the highest. Electrostatic spray painting, however, costs significantly more to retrofit than does HVLP and therefore is not considered as attractive as HVLP for the PNSY.

To retrofit a HVLP system, a regulator/filter assembly, air hose, control valve, quick disconnect, and HVLP spray gun are needed. The existing air compressors, expected to be adequate, need not be replaced.

Option 6 - Operator Training and Awareness

Paint and paint wastes comprise the second largest hazardous waste stream generated at PNSY. A program that encourages operator involvement and responsibility can reduce the amount of waste paint by controlling the amount of paint overspray, the amount of unused paint left in the can, and the amount of unusable paint resulting from partial solidification.

By outlining the waste minimization goals of the PNSY and distributing this information, supervisors and operators become aware of the goals as well as waste quantities generated, disposal costs, and current waste minimization efforts. The supervisors and operators are the key to the success of waste minimization programs.

When each operator is properly trained in the procedures and the use of equipment, waste caused by careless operating practices is avoided and material costs are reduced. Certain details of the waste minimization program can be written into process specifications.

Finally, feedback should be solicited from the operators to assess the effectiveness of the waste minimization efforts and to identify areas where further waste minimization is possible. New options that appear feasible should be explored.

Option 6 relates strictly to personnel and procedural changes. No new equipment or materials are necessary. Training can be done in-house and on-site by existing Naval personnel knowledgeable in the areas of waste minimization, general painting operations, and booth operating procedures. Applying Option 6 base-wide can reduce wastes generated in every painting department.

Option 7 - Recovery of Concentrated Citric Acid Solution

This batch process for recovering spent concentrated citric acid/TEA solution from derusting operations employs equipment used for similar processes but not specifically for citric acid derusting wastewaters.

The proposed recovery process includes three main removal operations: oil and grease (O&G), suspended solids, and dissolved metal. For O&G removal, the equipment, specifically designed for removal of oils from shipboard bilge waters, employs enhanced gravity separation and coalescer beds of polypropylene. It has a modular design that includes all necessary pumps and controls.

For removing suspended solids, a floating ceramic media backwash filter with an upflow service, downflow backwash design is recommended. Suspended solids with a size greater than 5 microns can be removed. The backwash cycle can be automatically initiated with a pressure differential switch, and the backwash (1% to 5% of treated volume) from the filter could be recycled to the storage tank or drummed for disposal.

The discharge from the filter collects in the recovery tank. A level control senses when a sufficient volume has been collected and shuts off the feed pump on the oil removal system. The electrodialysis (ED) unit is then energized. The proposed ED unit is a technology specifically designed to remove cations (e.g., iron, lead, trivalent chromium, cadmium) from acid baths. Although most often used to maintain hard chrome plating solutions, the ED unit has been successfully tested in the laboratory to maintain citric acid/TEA solutions. This technology consists of an electrochemical cell (cylindrical unit placed into recovery tank) and a cathode tank. The cell is designed with a set of anodes that contact the acid solution, a cation specific membrane, and a cathode within the membrane compartment.

During operation, the catholyte solution (caustic solution) is continuously circulated to the membrane compartment. The metal ions present in the spent citric acid/TEA solution are electrically driven through the membrane and are precipitated as hydroxides in the catholyte. Since the membrane is cation specific, anions are unable to pass through. The process is relatively slow (on the order of 2 to 4 wk), but it can be operated unattended. After the process is complete (determined by concentration of iron in citric acid/TEA solution), the ED unit is shut off. The solution is then tested to determine the concentration of citric acid and TEA; adjusted, as necessary; and recycled to the derusting operation.

Ranking of Options

The assessment phase includes collecting data, selecting target areas, reviewing data, and generating and screening options (Table 2).

The WM screening process consists of comparing WM options (WM options described on Worksheet 12) using standard criteria presented in the WM Assessment Manual. The criteria include various measures of the effect of WM on safety, cost, ease of implementation, and other relevant factors. Scores for individual WM options are determined by multiplying a weight factor, W (1 to 10), for each criteria by a score (1 to 10) or measure (termed R-value) for how well each WM option satisfies each criteria (Score = R x W). Then, the scores for each WM option are summed over all criteria to produce a single score for each WM option. As indicated in Table 2, the scores for the identified options range from 288 to 396.

The weighted values (W) for each criteria were set through an iterative process for an initial "first-cut," which was reviewed and modified by PNSY. The measures for each option (R) were estimated and where possible, these estimates were quantified (e.g., costs) and converted to R-values. For other measures, which could not be quantified, the R-values were estimated by the Science Applications International Corporation (SAIC) project members through data review and discussion.

Based on the results of the assessment phase, all identified options were considered to be within a narrow range and were, therefore, selected for further evaluation in the feasibility analysis phase.

Feasibility Analysis

The purpose of the feasibility analysis phase is to prepare a (1) technical and (2) economic evaluation of the WM options and to select options for implementation. The technical feasibility evaluation initially determines the nature of the WM option, either equipment-related, personnel/procedure-related, or materials-related. The economic feasibility evaluation includes a cost analysis of both capital and operating costs. The WM options evaluated during this project include five equipment-related options, one personnel/procedure-related option, and one materials-related option.

The technical and economic results of the feasibility analysis phase are summarized in Table 3. This table indicates for each option, the total capital investment, the net operating cost savings and the payback period (total capital investment/net operating cost savings).

To further evaluate the relative benefits of each option, the options were ranked (1 for the best to 7 for the worst) with respect to the net operating cost savings and the payback period. These rankings were then summed for each option and compared among all options and a final ranking was determined (1 for the best to 7 for the worst). These comparisons are shown in the final column in Table 3. Using savings and payback heavily weighs the evaluation in terms of annual cost savings since both criteria contain annual costs factors. Other techniques for comparing options may also be valid. Worksheet 17 is an alternative method, which calculates profitability based on cash flow.

Conclusions

The assessment of several WM opportunities at the PNSY yielded seven possible options. The relative comparison used in this study indicates that the best options appear to be: Option 6 - Awareness and Training; Option 1 - KRC-7X Dragout Reduction and Bath Maintenance; and Option 2 - Two-Stage Rinsing. Implementing these three options would cost $39,560 and result in an annual savings of $158,680. Implementing all seven options would cost

$144,982 and result in an annual savings of $246,180.

Option 7 involving the implementation of equipment for the recovery of citric acid/ TEA solution, appears to be a viable candidate for research, development, and demonstration.

It is important to note that the PNSY is not a commercial production facility but rather a government facility that is operated for revitalizing and repairing ships. As such, the payback period of the evaluated WM options may be different than that for commercial operations. Also, other WM options that were not evaluated in this study may be applicable to commercial operations.

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Table 2. Summary of WM Assessment Phase

Location/Process Waste Stream	Volume GPY	Hazardous Characteristics	Disposal Cost, $/yr	Raw Mat. Costs, $/yr*	WM Options	WM Option Screening Score
Building 990						
Aluminum Cleaning						
Spent KRC-7X (WS-1)	7,040	Low pH	$14,010	$46,120	Dragout Reduction and Bath Maintenance (OP-1)	383
Spent Rinse Water (WS-2)	45,760	Low pH	$70,928	$0	Two Stage Rinse (OP-2)	396
Spray Painting of Aluminum						
Paint Sludge (WS-3)	2,000	Toxic Metals/Ignitable	$3,760	$2,800	Booth Guard (OP-3), Sludge Dewatering (OP-4),	308, 288
					and HVLP Spray Painting (OP-5)	339
Used Paint Thinner (WS-4)	520	TM/Ignit/Toxic Organics	$978	$1,680	Awareness and Training (OP-6)	393
Unused Paint (WS-5)	Unk.	Toxic Metals/Ignitable	$350,000†	Unk.	Awareness and Training (OP-6)	393
Building 1028						
Spray Painting of Steel						
Paint Sludge (WS-6)	3,600	Toxic Metals/Ignitable	$6,768	$2,800	Booth Guard (OP-3), Sludge Dewatering (OP-4),	308,288
					and HVLP Spray Painting (OP-5)	339
Used Paint Thinner (WS-7)	520	TM/Ignit/Toxic Organics	$978	$1,680	Awareness and Training (OP-6)	393
Unused Paint (WS-8)	Unk.	Toxic Metals/Ignitable	Included Above	Unk.	Awareness and Training (OP-6)	393
Drydocks						
Citric Acid Derusting						
Conc. Citric Acid/TEA (WS-9)	15,000	Low pH, Toxic Metals	$45,750	$26,994	Electrodialysis Recovery System (OP-7)	

*Raw material costs are only given for materials considered to be at least partially recoverable.
†Includes entire shipyard.

Table 3. Summary of WM Feasibility Analysis Phase

Location/Process/ Waste Stream (WS)	Waste Minimization Options	Nature of WM Option	Capital Investment, $	Net Op. Cost Savings, $/yr	Payback Period, yr*	Rank Low to High (1-7)
Building 990						
Aluminum Cleaning						
Spent KRC-7X (WS-1)	Bath Maintenance (OP-1)	Equipment	$12,220	$44,190	0.3	2
Spent Rinse Water (WS-2)	Two State Rinse (OP-2)	Equipment	$3,116	$34,592	0.1	2
Spray Painting of Aluminum						
Paint Sludge (WS-3)	Booth Guard (OP-3)	Materials	$12,190	$10,890	1.4	6
	Paint Sludge Dewater. (OP-4)	Equipment	$9,550	$7,720	1.2	6
	HVLP Spray Painting (OP-5)	Equipment	$7,630	$8,170		5
Used Paint Thinner (WS-4)	Awareness & Training (OP-6)	Personnel/Proced.	$24,226	$79,900	0.3	1
Unused Paint (WS-5)	Awareness & Training (OP-6)	Personnel/Proced.				
Building 1028						
Spray Painting of Steel						
Paint Sludge (WS-6)	Booth Guard (OP-3)	Materials	See WS-3	See WS-3†	See WS-3†	
	Paint Sludge Dewater. (OP-4)	Equipment	See WS-3	See WS-3†	See WS-3†	
	HVLP Spray Painting (OP-5)	Equipment	See WS-3	See WS-3†		
Used Paint Thinner (WS-7)	Awareness & Training (OP-6)	Personnel/Proced	See WS-3	See WS-4†	See WS-4†	
Unused Paint (WS-8)	Awareness & Training (OP-6)	Personnel/Proced.	See WS-3	See WS-4†	See WS-4†	
Drydocks						
Citric Acid Derusting						
Conc. Citric Acid/TEA (WS-9)	ED Recovery System (OP-7)	Equipment	$76,050	$60,720	1.3	4

*Includes entire shipyard.
†Options 3 and 4 include both Build. 990 and 1028.

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The complete report, entitled "Waste Minimization Opportunity Assessment : Philadelphia Naval Shipyard," (Order No. PB91-125 690/AS; Cost: $31.00 , subject to change) will be available only from:
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