POLLUTION PREVENTION ASSESSMENTS FOR MARINE MAINTENANCE AND COMMERCIAL PRINTING INDUSTRIES

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ABSTRACT This paper represents the results of ten pollution prevention/waste minimization assessments performed on marine maintenance and commercial printing industries in the Hampton Roads area of the Commonwealth of Virginia. The pollution prevention project is the result of a working partnership (the Partnership) formed between Old Dominion University Department of Civil and Environmental Engineering (ODU) and Hampton Roads Sanitation District Industrial Waste Division (HRSD) for the Pollution Prevention Incentives for States (PPIS) grant awarded by the United States Environmental Protection Agency (EPA). Local businesses were provided with direct on-site technical consultation on waste reduction, and possible alternatives for the reduction or elimination of solid and hazardous waste, waste water discharges, and air emissions, were evaluated. Financial analyses of identified technology and procedural options were developed in order to prepare comprehensive reports for each business on findings and recommendations. Industry profiles are provided in order to establish the type of services rendered by the facilities participating within the program. Material usage, waste generation, and waste minimization recommendations are examined for both the marine maintenance and commercial printing industries. Proposed waste minimization recommendations for the marine maintenance industry include loss prevention, good housekeeping, solvent recycling, waste segregation, and the installation of an aerosol recovery system. Economic incentives have been addressed for both the aerosol recovery system and a solvent distillation unit. In addition to loss prevention and good housekeeping, waste minimization recommendations for the commercial printing industry include hazardous solvent source reduction, recycling of available markets, and silver recovery during photoprocessing operations. Successful implementation of the proposed measures is dependent upon each facility. Performance measures will be taken on a routine basis by HRSD personnel during regular inspections and should also be taken by plant personnel for optimum effectiveness.

KEYWORDS: pollution prevention, marine maintenance, printers

INTRODUCTION

Old Dominion University Department of Civil and Environmental Engineering (ODU) and Hampton Roads Sanitation District Industrial Waste Division (HRSD) formed a working partnership (the Partnership) for the Pollution Prevention Incentives for States (PPIS) grant. The Partnership was developed to help small and medium-sized industries in the Hampton Roads area of the Commonwealth of Virginia form pollution prevention/waste minimization programs within their facilities. The project combines strengths from both agencies and joins HRSD's informational resources and technical review staff with ODU's faculty and students. It represents a unique close working partnership involving an institution of higher learning and a regulatory entity. The program reflects a comprehensive and coordinated pollution prevention effort addressing the transfer of potentially harmful

pollutants across all environmental media, including air, water, and land.

Limitations such as time constraints, available personnel, and funding were overcome by utilizing students. Providing on-site pollution prevention assistance gave students an opportunity to gain valuable experience in the field. In addition, industries demonstrated enthusiasm as a result of the assessments being performed by personnel with no regulatory authority.

ODU and HRSD targeted two industry types for the PPIS grant project. Four on-site assessments were performed within the marine maintenance/ship repair category, and six assessments were provided within the commercial printing industry. The project provided businesses with direct on-site technical consultation on waste reduction, at no cost. Current waste management methods and technologies were reviewed, and possible alternatives for the reduction or elimination of solid and hazardous waste, waste water discharges, and air emissions were evaluated. Economic analyses of identified technology and process alternatives were assessed in order to obtain management approval. Environmental regulations governing waste management and promoting waste minimization were discussed, as well as the importance of proper environmental training.

METHODOLOGY

Prior to the pollution prevention opportunity assessment phase, a list of interested participants by industry type was generated through pre-assessment surveys sent out by HRSD. Facilities chosen to receive on-site assessments provided pre-site visit information by completing a pollution prevention/waste reduction opportunity assessment (OA) questionnaire. The waste minimization questionnaire was developed for each target industry and gathered information regarding the facilities' products, manufacturing processes, waste generation and management, and any current waste minimization methods employed.

Students received on-site training by HRSD inspection personnel during their routine pretreatment inspections. Experience was gained by training at different industries engaged in a variety of services, including metal finishing, food processing, marine maintenance, and water treatment. Extensive literature and technical on-line research preceded all assessments for the purpose of educating all parties involved in the project.

Actual on-site assessments included staff interviews, plant walk-throughs, and identification of current waste management and pollution control policies and methods. Documentation including Material Safety Data Sheets (MSDS), hazardous waste manifests, environmental permits, facility and process equipment diagrams, and product/raw material cost information was gathered for development of pollution prevention strategies. Collection and analysis of data, development of recommendations, and report preparation followed each facility visit.

Individual reports developed for each assessment included data gathered on the facility, production processes, waste generation, previous efforts of waste management, and proposed recommendations on waste minimization, coupled with relevant financial analysis of identified technology and procedural options. Reports were reviewed by HRSD's technical staff for comments and then sent to participating industries.

Follow-up procedures included active participation from all participating facilities through surveys and information exchange workshops, the generation of printed information targeting each industry category, and the provision of readily available information exchange services. Measurements of waste minimization progress will be taken on a continual basis in order to evaluate the success of the program.

INDUSTRY PROFILES AND WASTE MINIMIZATION RECOMMENDATIONS

Marine maintenance and repair

Company profiles

The marine maintenance and repair industry involves those establishments engaged in building and repairing ships and barges, and the conversion and alteration of ships. Three of the four participating facilities primarily repair U.S. Navy and government vessels with occasional work performed on commercial ships. Industrial activities consist of modification and repair, abrasive blasting, painting, and underwater hull repairs. Fabrication of smaller parts is performed in the machine, pipe, and parts shops. Transfer operations include the removal of nonsanitary waste water generated from the ship and cleaning operations, and the transfer of fuel oil.

One facility participating in the program is unique in the sense that all ship repair work is mobile. Generator and motor cleaning is performed at the location where the ship was docked. At the facility, sheet metal fabrication is predominant for the manufacture of metal lockers installed on the ships.

The number of employees at the four participating facilities ranged from 200 to 500. Table 1 characterizes the major operations and major waste streams accompanied with each of the companies.

Material usage and waste generation

Typical raw materials associated with the

TABLE 1. MARINE MAINTENANCE AND REPAIR COMPANY PROFILES.

Company	Major Operations	Major Waste Streams
A	painting	paint waste
	outdoor blasting	blasting waste
	machine work	solvent waste
	transfer operations	oily waste water
B	metal working	liquid paint waste
	preservation coatings	solid paint waste
	underwater hull repair	blasting waste
	transfer operations	waste oil
C	generator/motor cleaning	contaminated water
	sheet metal fabrication	waste oil
	structural repair	blasting waste
	blasting and coating	paints/solvents
D	tug and barge repair	blasting waste
	steel repairs	paint waste
	painting	solvent waste
	outdoor blasting	asbestos
	insulation	

marine maintenance and repair facilities are shown in Table 2. Paints, solvents, and blasting media account for most of the materials entering the yards. Several of the sites contain aboveground and underground storage tanks for storage of diesel fuel, fuel oil, and gasoline.

Individual waste streams generated from the major operations and expended raw materials were difficult to quantify due to lack of inventory control and inadequate waste segregation. In some cases, liquid and solid paints, as well as solvent wastes, were combined within the same drum for hazardous waste disposal. Improper hazardous waste storage and mishandling contributed to high disposal costs and wasted materials. Typical generation rates of the most common waste streams for one facility, Company B, are represented in Table 3.

Waste minimization recommendations

Waste minimization recommendations for the marine maintenance and repair facilities involved in the program include loss prevention and good housekeeping, installation of an aerosol recovery system, the establishment of a solvent recycling program, hazardous solvent source reduction, and proper storage of spent sandblast grit. It is through proven techniques by various shipyards in the United States that these recommendations have yielded success for similar case scenarios. Table 4 provides nonquantitative evaluations of four waste minimization alternatives. Each alternative was rated as either having a beneficial effect (+), no effect (0), or a negative effect ( ), on each of 11 evaluation criteria [1].

Loss prevention and good housekeeping techniques are an essential part of successful waste minimization and effective source reduction. It involves strict inventory control, proper storage of hazardous materials, waste segregation, and spill

TABLE 2. RAW MATERIAL USAGE FOR THE MARINE MAINTENANCE AND REPAIR INDUSTRY.

Process/Operation	Raw Materials
Painting	epoxy, latex-based, water-based, vinyl, and marine solvent paints; primer; thinner; solvents
Abrasive blasting	coal slag, sand, and glass bead blasting media
Machine work	degreasing solvents; cutting fluids; lubricating grease; oils; chlorinated solvents
Transfer operations	diesel fuel; No. 2 fuel oil; gasoline

TABLE 3. 1995 WASTE GENERATION RATES FOR MARINE MAINTENANCE COMPANY B.

Waste Description	Generation Rate	Unit Disposal Cost	Total Disposal Cost	Waste Destination
Blasting Waste (coal slag)	11,241,920 lb	$34/short ton	$ 191,113	Recycle
Waste Oil	2,199,632 lb	Free	---	Fuel blending
Blasting Waste (glass bead)	27,225 lb	$400/55 gal drum	$ 24,400	Hazardous waste landfill
Liquid Paint Waste	24,400 lb	$90/30 gal drum	$ 5,490	Incineration
Solid Paint Waste	11,900 lb	$225/30 gal drum	$ 13,500	Incineration
Cyanide/Metal Waste	626 lb	$1/lb	$ 626	Treatment

control methods.

Purchasing or stockroom staff should track and control all materials entering the yard, and monitor their disbursement throughout the various shops by establishing a computerized inventory system. Personal computers are already located in storage rooms at all of the facilities and would therefore make this option relatively inexpensive.

Control over the issue of materials for a particular task can reduce wasteful usage and ultimately reduce purchase costs. The quantities of materials should be limited to the approximate amount required to complete a task. The issuance of large quantities can result in wasteful practices and cost a facility unnecessary expenses. Just-in-time ordering practices should be instituted to ensure that materials arrive only when they are needed; this will minimize the potential damage of materials that are stored and moved around the site.

Stockroom staff should also monitor the expiration dates of materials; one way of doing this is by setting up a computer program that would easily access expiration dates of all materials. For example, a designated stockroom employee can check on the first day of every month for all materials that have an expiration date within the following 60 days. These materials can then be closely monitored to ensure they are distributed first.

Another practice that is encouraged is the *proper containment and leak control* of wastes stored in hazardous waste storage areas. It is recommended that all drums containing hazardous materials and partially full paint cans be stored on pallets and not directly on the ground. Some type of secondary containment should also be provided to help contain possible spills. Laying a form of plastic sheeting or tarp on the ground beneath all pallets and containers could be easily implemented at minimal cost, yet substantially prevent the leachate of hazardous chemicals to the underlying soils. Care should also be taken to ensure that hazardous materials are not stored on sloped surfaces that could allow them to enter

TABLE 4. QUALITATIVE ASSESSMENT OF WASTE MINIMIZATION OPTIONS.

Evaluation Criteria	Waste Minimization Options			
	Inventory Control	Aerosol Recovery System	Solvent Recycling	Container Transfer of Paint
Waste Reduction Potential	+	+	+	+
Space Requirements	0	0	0	0
Modifications of Plant Processes	0	0	0	0
Impact on Operations	0	0	0	+
Manpower Requirements	0	0	0	0
Permit Requirements	0	0	+	0
Proven Techniques	+	+	+	+
Reduction in Toxicity	+	+	+	+
Employee Health and Safety	+	+	+	+
Economic Factors	+	+	+	+
Consistent with Other Environmental Programs	+	+	+	+

nearby surface waters [2].

Waste segregation should also be adopted as a routine management practice. Hazardous and nonhazardous waste streams should be separated, and materials that are incompatible should not be stored together or adjacent to one another. There should be stringent monitoring of hazardous material storage to ensure that improper mixing of incompatible waste streams is not present [3].

Control methods should be implemented in order to minimize spills and leaks. Specific approaches to product transfer methods and container handling can effectively reduce product loss. Spigots, pumps, and funnels should be used when transferring liquid materials from storage containers to process equipment. Evaporation can be controlled by using tight-fitting lids, spigots, and other equipment. All containers containing paints, solvents, and other hazardous materials should remain closed at all times. Reduction in evaporation can increase the amount of available material and result in lower solvent purchase cost [4].

Spill response plans that are directed towards the event of an emergency spill, and address spill mitigation procedures, aboveground storage tanks, spill history, and employee training have been established at all of the facilities. In the event of a major spill, contracting companies are usually retained to assist in containment and cleanup procedures.

Source reduction focuses on the reduction or elimination of toxic solvents into the environment. In that capacity, marine maintenance and repair facilities have a lot of potential to expand. The extreme waste of paints can be eliminated by either purchasing paints in one gallon containers, if possible, or by transferring paints from five gallon containers to smaller containers. These techniques have proven successful at several of the facilities that have participated in this pollution prevention program. Distributing paint to smaller containers allows workers to check out small amounts of paints when needed. Resealing the lids on all paint containers when not in use will further reduce the unnecessary wastage of paints. Cans should not be left open for any period of time in order to prevent solidification of the paints. Two-part paints that are a combination of two separate paint compositions can also be mixed in one gallon cans, reducing the disposal of unused portions. The transfer of paints ordered in five gallon containers to smaller containers not only reduces waste, but can save companies unneeded expenditures on hazardous waste disposal.

Hazardous solvent source reduction remains a critical issue with the eventual phase-out of certain halogenated chemicals. Cleaning solvents containing trichloroethylene (TCE) and 1,1,1-trichloroethane (TCA) are both hazardous and ozone-depleting solvents [5]. Several substitutes have been recommended in order to reduce the volume of halogenated solvents. By reducing the volume of these substances, companies can reduce future liability and increase environmental compliance.

Current procedures for disposing of aerosol cans at a particular facility, Company A, were not in accordance with federal, state, and local regulations. The most feasible solution was the installation of an *aerosol recovery system*. The system safely relieves the pressure of the aerosol can while residual liquids are collected in the drum.

Environmental benefits of the installation of an aerosol recovery system include the reduction of hazardous waste transportation and handling, a source of recyclable scrap steel, and RCRA compliance. Economically, as shown in Table 5, the system can save Company A $10,000 in waste disposal costs, and from an investment standpoint, produces a highly favorable payback period of less than two months.

The installation of a *solvent distillation* system was investigated for one facility, and calculations performed in Table 6 offer an economic incentive for consideration of this alternative. Consideration was given to two systems, a unit with a batch capacity of five gallons, and a second unit with a batch capacity of fifteen gallons. The compact design of the units permit installation in minimal space. The results of the cost analysis indicated significant monthly cost savings from the reduction in solvent purchases and reduced waste disposal costs. The investment payback periods for both units were less than ten months. The selection of a particular unit is dependent upon company solvent usage.

Installation of a distillation system reduces solvent purchases and waste disposal costs by purifying solvents for reuse. Liability is reduced for transporting hazardous waste off-site, and regulatory compliance requirements, such as record keeping, reporting, and tracking, are simplified [6].

Another concern and proposal was the proper *storage of spent sandblast grit*. A temporary plastic sheeting or tarp should be placed over the sandblast grit pile to eliminate contact with rainwater and high

TABLE 5. COST ANALYSIS FOR AEROSOL RECOVERY SYSTEM.

• Annual cost savings from reduced need to dispose of aerosol cans	= $ 10,000
• Cost of aerosol can recycling system	= $ 695
• Estimated annual operating costs	= $ 2,400
• Required liquid residual disposal costs	= $ 800
• Net annual benefit = [$10,000-$2,400-$800]	= $ 6,800
• Payback period = cost/annual benefit = $695/$6,800	= 1.2 months

TABLE 6. COST ANALYSIS FOR ON-SITE SOLVENT RECYCLING.

• Projected monthly cost savings	
for reduction in solvent purchases	= $ 567
for waste disposal cost	= $ 736
• Cost of solvent distillation unit	
Purchase cost (5 gallon unit)	= $ 4,650
Purchase cost (15 gallon unit)	= $ 7,975
Start-up costs	= $ 5,000
Monthly operating costs	= $ 8
• Net monthly benefit =[$567+$736-$8]	= $ 1,295
• Payback period = cost/monthly benefit	
for 5 gallon unit	= 7.5 months
for 15 gallon unit	= 10 months

winds. Scrap metal parts, blocks, or tires can be easily used to hold the cover in place. Since the waste is considered non-hazardous, based on TCLP results, and since the location of the pile does not cause potential contact to process water or storm water, construction of an impervious paved storage area is not required at this time. A tarp should be used underneath the grit pile according to the Virginia Solid Waste Management Regulations (VSWMR). However, if a TCLP test fails and the waste is deemed hazardous material, proper containment would be necessary. It is recommended that the hazardous amounts be transferred into 55 gallon drums and transferred through proper disposal means.

Commercial printing industry

Company profiles

The commercial printing industry involves those establishments engaged in the printing of materials by one of the common printing processes, such as lithography, gravure, flexography, letterpress, or screen. Services such as bookbinding, typesetting, engraving, photoengraving, and electrotyping are included within this industry, as well as establishments involved in the publication of newspapers, books, and periodicals [7].

Four of the five most common printing processes were practiced among the six local businesses that were assessed as part of the pollution prevention project. Flexography, which uses a flexible plastic or rubber plate in a rotary web press, was demonstrated in the printing of labels and corrugated packaging [8]. Offset lithography which produces a higher quality of printing, was observed at two facilities in the production of packaging, brochures, greeting cards, and posters. One facility used gravure printing for large volume and high speed runs for the high-quality printing of cigarette packaging. This process is extremely efficient and allows for the production of 300,000 cigarette cartons per hour. Screen printing, a small segment of the printing industry, was utilized at one facility for the production of posters and banners.

Several of the participating facilities incorporate platemaking and photoprocessing operations within their services. These produce waste streams containing silver, and recovery units are required in order to remove the silver content from the waste water prior to discharge to the sanitary sewer.

The number of employees at the six participating facilities ranged from 32 to 425. Several of the facilities operate on a 24-hour basis with rotating shifts in order to meet the required workload. Table 7 characterizes the major operations, processes, and major waste streams accompanied with each of the companies.

Material usage and waste generation

Typical raw materials associated with the commercial printing facilities are shown in Table 8. The principal raw materials used within the industry are inks and substrates. Paper substrates are predominant at the six facilities with the usage of vinyl, foil, and polyester substrates used only in the screen printing process at Company 2. Gravure cylinders, photographic films, cleaning solvents for printing presses, and photoprocessing and plate processing chemicals are also used throughout the facilities. Table 9 shows the typical monthly usage rates of specific materials for the largest participating facility, Company 4.

General types of waste generated within the facilities include ink and solvent wastes, solid waste including paper, corrugated boxes, wooden pallets, and photographic processing wastes [9]. Recycling opportunities for solid waste materials were incorporated into several of the companies' operations. However, waste matrix produced from the printing of labels posed high solid waste costs; the adhesive and lamination of the scrap waste prohibits it from being recycled, causing a large volume of solid waste at several of the facilities.

Waste minimization recommendations

Waste minimization recommendations for the commercial printing facilities involved in the program include product substitution, recycling of available markets, and silver recovery during photoprocessing operations. Good operating practices along with spill control measures are also emphasized for an

TABLE 7. COMMERCIAL PRINTING COMPANY PROFILES.

Company	Major Operations (Processes)	Major Waste Streams
1	pressure-sensitive label manufacturing; stencil manufacturing (flexography)	corrugated boxes wood pallets steel and plastic bands
2	pressure-sensitive label manufacturing; banner production; photoprocessing (flexography and screen printing)	ink waste pressure-sensitive paper solvent wastes waste water fixer and developer waste
3	corrugated container printing (flexography)	corrugated waste waste water
4	high quality package printing; platemaking and photoprocessing (offset lithography and rotogravure)	waste inks coatings solvent waste paper waste photochemicals
5	corrugated cardboard manufacturing; corrugated container printing (flexography)	sludge from papermaking paper waste solvent waste ink waste
6	poster, magazine, catalog, and brochure printing; photoprocessing (sheetfed offset lithography)	ink waste contaminated waste water cleaning rags solvent waste photographic waste

TABLE 8. RAW MATERIAL USAGE FOR THE COMMERCIAL PRINTING INDUSTRY.

Process	Raw Materials
Flexography	water-based inks; paper substrates; cleaning solvents
Offset lithography	solvent-based inks, petroleum-based inks; paperboard; solvents; adhesives
Gravure	solvent-based inks; paper substrates; rotogravure cylinders
Screen printing	vinyl, foil, and polyester substrates; solvent-based inks
Plate preparation and photoprocessing	fixer; developer; image finisher; replenisher; rinse water

effective waste minimization program.

Most of the cleaning solvents used within the printing industry are needed for effective removal of ink buildup on the printing presses. Several alternatives have been sought to replace some of the more hazardous chemicals that are currently being used.

For solvent-based inks, the usage of these inks is strictly client-based. All facilities that are employing operations using these solvents are doing so as a request by the customer. Water-based inks are primarily used at the participating facilities eliminating significant amounts of volatile organic compound (VOC) emissions.

One facility operating a photoprocessing unit was prohibited from discharging process water to the sanitary sewer. This presents them with high disposal costs of the contaminated waste water. To reduce hazardous waste disposal costs, the facility must obtain an industrial discharge permit from the local sanitation department to discharge process water from the operation. Recommendations regarding the attainment of the necessary permit and limitations which must be met have been made. Table 10 shows the average waste rates associated with the film processing operation of Company 4.

Good operating practices should be utilized in every industry. Proper documentation of inventory and material tracking is necessary to avoid loss of products or wasted materials. Materials should be used on a "first-in, first-out" basis to eliminate chemical expiration of certain substances. Modification in ink inventory and ordering smaller quantities can alleviate the problem of excess amounts of less commonly used inks. Raw material order quantities should correlate with the required amounts needed for specific jobs, and container sizes should be economically feasible by volume, as well as in accordance with waste minimization goals [10].

RESULTS AND CONCLUSION

The success of these waste minimization assessments is dependent upon several factors. Waste minimization recommendations and solutions must be beneficial and yield valuable environmental results. Usually compliance and waste reduction measures depend on the costs of implementation. Technological changes must be easy to facilitate and profitable for environmental management support.

TABLE 9. MONTHLY USAGE RATES OF MATERIALS AT COMPANY 4.

Material	Amount Used
Substrate (paperboard)	2,500 tons
Rotogravure printing inks	50,000 lbs
Off-set lithography printing inks	5,000 lbs
Solvents	104,000 lbs
Isopropyl Acetate	67,000 lbs
Isopropyl Alcohol	12,000 lbs
N-propyl Acetate	10,000 lbs
Toluene	8,000 lbs
Ethyl Acetate	5,000 lbs
Ethyl Alcohol	2,000 lbs

Another essential point found in this study is the effectiveness of proper employee environmental training. It was noticed that employees who were educated on environmental requirements and regulation took better approaches to reducing waste. Successful implementation by the facility is dependent on all of these factors, and measuring performance in all areas is necessary in the improvement process.

Some of the proposed measures for implementation that would determine the impacts of the recommendations are as follows: large annual cost savings, significant impact of reduction of hazardous waste shipments, simplification of the regulatory requirements (i.e. permit applications), elimination of future liability, and an improved health and safety environment. These measures may be evaluated by recording actual mass flows, identifying raw materials, products and waste streams, taking regular readings of mass flows, and training personnel in data interpretation and analysis. Improvements will be monitored through measurements taken during HRSD's pretreatment inspections and by plant personnel on a routine basis.

Proper employee environmental training is an essential part of any waste minimization program. Employees from all levels of management need to be educated on the environmental requirements and regulations that impact their operations. Without employee environmental awareness and cooperation, no pollution prevention plan will be a success [11].

The results of this waste minimization study show how two organizations can combine their own strengths and provide the most comprehensive pollution prevention services to businesses within the Hampton Roads area.

ACKNOWLEDGMENTS

This project, entitled "Pollution Prevention Incentives for the States," was awarded by the Region III Environmental Protection Agency (Grant #352791).

TABLE 10. FILM PROCESSING WASTE RATES GENERATED AT COMPANY 4.

Operating Unit	Waste Stream	Avg. Monthly Waste Rates
Wash up sink	rinse water	800 gal
Roller wash	press wash water	1,350 gal
Positive plate processor	developer	20 gal
	pre-bake solution	6 gal
	rinse water	800 gal
Negative plate processor	developer	4 gal
	pre-bake solution	2 gal
	rinse water	80 gal
AGFA proofing system	developer	80 gal
	fixer	40 gal
	rinse water	140 gal
Film processor	developer	100 gal
	fixer	100 gal
	rinse water	60 gal
Colorlink developer	developer	8 gal
	rinse water	20 gal

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