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ENVIRONMENTAL RESEARCH BRIEF

Waste Minimization Assessment for a Manufacturer of Commercial Ice Machines and Ice Storage Bins

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Abstract

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of hazardous waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). The WMAC team at Colorado State University performed an assessment at a plant that manufactures commercial ice machines and ice storage bins. The surface treatment of fabricated steel parts, parts washing, and treatment of wastewater generate the majority of this plant's waste. The team's report, detailing findings and recommendations, indicated that the greatest waste reduction would result from reusing rinse water in the plant's five-stage washer for fabricated parts.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title, which is available from the authors.

Introduction

The amount of hazardous waste generated by industrial plants has become an increasingly costly problem for manufacturers and an additional stress on the environment. One solution to the problem of hazardous waste is to reduce or eliminate the waste at its source.

University City Science Center (Philadelphia, PA) has begun a pilot project to assist small- and medium-size manufacturers who want to minimize their formation of hazardous waste but who lack the in-house expertise to do so. Under agreement with EPA's Risk Reduction Engineering Laboratory, the Science Center has established three WMACs. This assessment was done by engineering faculty and students at Colorado State University's (Fort Collins) WMAC. The assessment teams have considerable direct experience with process operations in manufacturing plants and also have the knowledge and skills needed to minimize hazardous waste generation.

The waste minimization assessments are done for small- and medium-size manufacturers at no out-of-pocket cost to the client. To qualify for the assessment, each client must fall within Standard Industrial Classification Code 20-39, have gross annual sales not exceeding $50 million, employ no more than 500 persons, and lack in-house expertise in waste minimization.

The potential benefits of the pilot project include minimization of the amount of waste generated by manufacturers, reduced waste treatment and disposal costs for participating plants, valuable experience for graduate and undergraduate students who participate in the program, and a cleaner environment without more regulations and higher costs for manufacturers.

Methodology of Assessments

The waste minimization assessments require several site visits to each client served. In general, the WMACs follow the procedures outlined in the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). The WMAC staff locates the sources of hazardous waste in the plant and identifies the current disposal or treatment methods and their associated costs. They then identify and analyze a variety of

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ways to reduce or eliminate the waste. Specific measures to achieve that goal are recommended and the essential supporting technological and economic information is developed. Finally, a confidential report that details the WMAC's findings and recommendations (including cost savings, implementation costs, and payback times) is prepared for each client.

Plant Background

This plant manufactures commercial ice machines and ice storage bins. Typically, 270 employees produce 26,000 ice machines and 12,500 ice bins annually. Areas of the plant operate between 2,210 and 7,488 hr/yr.

Manufacturing Process

The framework and outer body parts of the products are fabricated from galvanized and rolled steel sheets. The sheet metal is cut to size, punched, and drilled by brake presses and numerically controlled punches.

Those steel parts are then sent through a five-stage washer to prepare their surfaces for coating. The washer consists of an enclosed spray booth through which a conveyor passes. The first stage degreases the steel parts with an aqueous spray of potassium hydroxide cleaner. Overspray and excess fluid drain back into a 2,000-gal collection tank for reuse. Waste is generated only when the tank is dumped about once each month. All of the wastewaters from the washer drain to the on-site wastewater treatment unit and are eventually sewered and fed to the POTW.

The second stage of the washer is a continuous rinse that sprays the metal parts with tap water to remove the cleaner and remaining contaminants. A tank below the spray nozzles collects rinse water that drains from the parts. This stage is designed so that clean tap water is sprayed onto the parts last. A pump supplies high-pressure water from the collection tank to provide initial rinsing. In addition to a continuous overflow of about 8 gpm of rinse water, the 1,200-gal collection tank is dumped on a daily basis.

The third stage sprays an aqueous solution of iron phosphate/phosphoric acid (typical pH of 5.5) on the parts. The phosphating solution reacts with the metal surface to provide an amorphous coating of iron oxides and phosphate that serves as a base for the powder coating. The phosphating stage only generates waste when the collection tank is dumped, typically on a monthly basis.

The fourth stage is another tap-water rinse to remove excess phosphating solution. In addition to a continuous rinse water overflow of about 9.5 gpm, the 650-gal collection tank is dumped on a daily basis.

The fifth stage of the washer is a closed-loop, chromated-water spray rinse, which provides a mild conversion coating to the parts. Metal parts are sprayed with about 33 gpm of an aqueous solution to which chromic trioxide has been added. The collection tank is connected to a treatment unit that contains three ion-exchange cartridges. Treatment of the chromated water is performed on a batch basis, typically every three weeks; treated liquid drains to the wastewater treatment unit. The spent resin cartridges are drummed and returned to the supplier for recycling. Following this rinse, the parts are air dried.

Next the steel parts are painted with powder coating and baked in a 400°F natural gas-fired oven to bond the powder coating to the parts' surfaces. These finished cabinet components are then sent to the final assembly area.

This plant manufactures onsite the flaker barrel/evaporator assembly and the down chute for directing the flow of ice flakes for the flaked ice machines produced. Brass tubes for the flaker barrels are milled, drilled, and threaded. Copper tubing is then wrapped around the barrel and the assembly is cooled with water. A heated brass shell is shrink-fitted onto the cooled assembly and brazed onto the barrel.

The flaker barrel/evaporator assemblies are then sent through a bright dip process that provides corrosion protection to the assemblies. Brass barrels and brass/copper evaporator assemblies are first dipped in an aqueous brightening solution containing nitric acid and calcium nitrate for about 75 seconds. The solution loses its effectiveness after cleaning about 100 evaporators and is drained and regenerated about twice per week. The spent solution, which contains copper sulfate and copper nitrate crystals, is drummed and returned to the supplier to recover the copper.

A dead rinse bath and heated rinse bath of tap water follow cleaning. After rinsing, the barrel assemblies are placed on drip boards to allow liquids to drain back into the rinse baths. These rinses are drained daily to the wastewater treatment unit. Rinses typically contain copper and lead in solution, along with reagents carried into the rinse baths as drag-in.

A chemical sealant is then applied to the assemblies to allow for service in food-related areas. The barrels are plunged quickly into a succession of baths containing an aqueous solution of soda ash, tap water, and an aqueous sealant containing isopropyl alcohol and potassium hydroxide. These baths are drained and regenerated about once per week. The spent solutions flow to the wastewater unit for neutralization and disposal.

Following the chemical cleaning and sealing, the finished barrel/evaporator assemblies are placed into a mold. Self-skinning polyurethane foam insulation is blown into the mold and onto the outer surface of the assemblies.

Down chutes are fabricated from sheet metal and then insulated with blown polyurethane foam.

The evaporators for the ice machines that make cubed ice are also manufactured in-house. The evaporator assembly consists of a grid of criss-crossed copper strips that form the framework inside a copper pan.

All copper parts are first chemically cleaned in a degreasing solution and an aqueous solution of 5% hydrochloric acid. The tanks are drained and replenished twice a week. Spent solutions flow to the wastewater treatment unit for neutralization and disposal.

Slots are then cut in the copper strips using punches. The pans are formed from copper sheets. The grid, which is made up of copper strips, is then assembled in the pan.

Copper tubing is bent into a serpentine shape and bonded to the reverse side of the copper pans with solder in an electric soldering oven. The evaporator assemblies are then cleaned in an enclosed washer to remove excess solder flux that clings to the copper surfaces. The cleaning solution contains a mild acid to remove corrosion and metallic oxides. Overflow from the washer drains to the wastewater treatment unit. The cuber evaporator assemblies are then sent offsite for tin plating.

In the final assembly area, completed evaporator assemblies and painted panels are assembled with motors, pumps, condensers, controls, and other parts to form flaked- and cubed-ice machines. Tubing is brazed together and tested for leaks in separate pressure tests with air and Freon 22. Further vacuum tests are performed on the completed refrigeration system. The units are then charged with either Freon 502 or Freon 12. Each ice maker is tested to assure quality ice production. Final insulation and outside panels are installed on the ice makers before they are packed and stored in the finished-goods warehouse to await shipping.

Ice bins are constructed of sheet metal panels with a plastic inner liner. Polyurethane foam is placed between the sheet metal and the plastic by a high-pressure foaming system. Final assembly includes cleaning and installing doors. Completed bins are packed and stored in the finished-goods warehouse to await shipping.

Wastewater from various operations in the plant drains to a holding tank. When the tank becomes full, the water is pumped to an acidification tank, where sulfuric acid is added to lower the pH to between 3.5 and 1.9. An aqueous solution of slaked lime is added in an initial neutralization tank to precipitate metal hydroxides and raise the pH to between 3.5 and 6.5. The pH is raised to between 6.0 and 9.5 in a second neutralization tank to allow for discharge to the POTW. After neutralization, a polymeric flocculent is added; the resulting sludge and supernatant are then forced through a filter press. From analytical tests performed by company personnel and outside labs, the dried sludge is known to contain copper and lead hydroxides in small amounts and is classified as non-hazardous waste. The sludge is therefore hauled to a non-hazardous waste disposal facility, where it is incorporated in the formulation of concrete. The supernatant liquid is discharged to the POTW as industrial wastewater.

Other sources of waste from this process include the following:

- Petroleum naphtha is used to clean tools and dies. Spent solvent is exchanged for fresh solvent and recycled by the supplier.
- Methylene chloride is used to clean the nozzle that mixes isocyanate and resin to form the polyurethane foam insulation for flaker barrel assemblies and down chutes. The nozzle must be cleaned out quickly after each use because the foam will set in about 20 seconds. A combined solution of waste polyurethane and spent methylene chloride is drummed and shipped to a hazardous waste facility.
- Waste oil is generated from annual drainage of hydraulic fluid reservoirs in metal-forming machines. Vacuum pumps from the testing area are occasionally drained and replenished. These streams are combined and sent to a non-hazardous waste oil recycling firm that filters and dewaters the oil for use as industrial boiler fuel.

Existing Waste Management Practices

The following waste minimization techniques have been implemented at this facility:

- A formal, written waste minimization policy has been defined by management, complete with cause champions.
- Powder coatings have been used since 1985 to replace solvent-based paints for metal parts.
- Organic cleaning wastes have been reduced in the bin-foaming area by the installation of the high-pressure foaming system.
- Excess metal is segregated onsite and sold to a scrap-metal dealer for recycling.
- A preventive-maintenance program has been developed for the machinery used in metal-forming operations.
- Waste oils, spent bright dip solutions, spent solvent, and ion-exchange cartridges from the final stage in the surface-treatment process are recycled.
- The final rinse in the washer prior to powder coating is a closed-loop rinse that involves separate treatment with an ion-exchange unit.
- Rinse water flow rates in the washer prior to powder coating have been reduced to the lowest possible levels deemed feasible by company personnel.
- Counterflow rinsing is used within the rinse stages of the washer prior to powder coating. Within each rinse stage, the initial rinse uses water from the drainage-collection tank, and the final rinse is fresh tap water.
- A dead-rinse tank is used in the bright dip process to collect drag-out before workpieces are dipped in heated rinse water.
- Drain boards are used following rinses in the bright dip process.
- Wastewater treatment sludge is partially dewatered by a filter press.
- Methylene chloride replaced methyl ethyl ketone (MEK) in 1984 to clean foamer nozzles for the flaker assemblies.
- Drip bars are used for the degreasing bath and acid bath of the small parts washer.

Waste Minimization Opportunities

Table 1 summarizes the principal sources of waste, their amounts, the management method applied and the associated costs.

Table 2 gives a brief description of the waste minimization opportunities recommended for this plant, the current plant practice, together with savings and cost data.

It should be noted that, in most cases, the economic savings of the minimization opportunities result from the need for less raw material and from reduced present and future costs associated with hazardous waste treatment and disposal. Other savings not quantifiable by this study include a wide variety of possible future costs related to changing emissions standards, liability, and employee health. It should also be noted that the savings given for each opportunity reflect the savings achievable when implementing each waste minimization opportunity independently and do not reflect duplication of savings that would result when the opportunities are implemented in a package.

This research brief summarizes a part of the work done under Cooperative Agreement No. CR-814903 by the University City Science Center under the sponsorship of the U.S. Environmental Protection Agency. The EPA Project Officer was Emma Lou George.

Table 1. Summary of Current Waste Generation

Waste Stream	*Waste Generated*	*Annual Quantity Generated (gal)*	*Management Method*	*Annual Waste Management Costs($)*
Liquid Waste				
A. Surface Treatment:				
Cleaner (Stage 1)	*Tap water laden with dirt, oil, and potassium hydroxide cleaner*	*24,000*	*Pretreated and sewered*	*40*
Rinse (Stage 2)	*Tap water laden with dirt, oil, and potassium hydroxide cleaner*	*2,545,900*	*Pretreated and sewered*	*4,280*
Iron Phosphate (Stage 3)	*Tape water laden with iron phosphate*	*14,400*	*Pretreated and sewered*	*30*
Rinse (Stage 4)	*Tap water laden with iron phosphate*	*2,781,500*	*Pretreated and sewered*	*4,680*
Chromated Rinse (Stage 5)	*Closed-loop rinse water laden with hexavalent chromium*	*16,900*	*Recycled within closed loop; periodically treated through ion-exchange and sewered. Filters returned to supplier for reclamation*	*30*
B. Bright Dip:				
Brightener	*Spent brightener containing copper nitrate and copper sulfate crystals*	*660*	*Returned to supplier for copper reclamation*	*1,620*
Soda Ash	*Spent sodium hydroxide*	*1,000*	*Pretreated and sewered*	*0*
Sealer	*Spent sealer containing isopropyl alcohol and potassium hydroxide*	*1,000*	*Pretreated and sewered*	*0*
Rinses	*Tap water laden with brightener, sealer, soda ash, and copper in solution*	*10,300*	*Pretreated and sewered*	*20*
C. Copper Parts Washer:				
Degreaser	*Tap water containing alkaline degreaser, grease, and oil*	*10,400*	*Pretreated and sewered*	*20*
5% HCl	*Tap water containing hydrochloric acid*	*10,400*	*Pretreated and sewered*	*20*

(continued)

Table 1. *Continued*

Waste Stream	Waste Generated	Annual Quantity Generated (gal)	Management Method	Annual Waste Management Costs($)
Liquid Waste (continued)				
D. Other:				
Machine washer	*Tap water containing acid salts*	*3,120,000*	*Pretreated and sewered*	*5,240*
Solvent washer	*Spent petroleum naphtha*	*250*	*Returned to supplier for reclamation*	*420*
Nozzle cleaning	*Methylene chloride and polyurethane*	*170*	*Disposal at hazardous waste facility*	*1,770*
Waste oil	*Used hydraulic and vacuum pump oil*	*750*	*Reclaimed offsite as boiler fuel*	*40*
Freon	*Discharged Freon*	*N/A*	*Exhausted from plant*	*N/A*
Solid Waste				
A. Wastewater Treatment:				
Sludge	*Non-hazardous metal hydroxide sludge with grease and oils*	*18,200*	*Disposal at sanitary landfill*	*6,300*

Table 2. *Summary of Recommended Waste Minimization Opportunities*

Present Practice	Proposed Action	Waste Reduction and Associated Savings
The rinse from stages two and four of the five-stage washer are dumped to the sewer on a daily basis.	*Redirect the rinse water overflow from the fourth stage for reuse in the second stage rinse thereby eliminating the fresh water make-up in the second stage. Waste reduction and cost savings will result from eliminating the disposal of spent brightener and rinses. Cost savings will result from the reduced amount of water that must be purchased, treated, sewered.*	*Waste reduction = 2,171,520 gal/yr* *Cost reduction = $4,630/yr* *Implementation cost = $800* *Simple payback = 0.2 yr*
Flaker barrel evaporator assemblies are cleaned in the bright dip line.	*Install a plastic media blasting unit to replace the existing chemical cleaning line. The proposed system would use air pressure to propel plastic granules that provide mildly abrasive cleaning. Waste reduction will result from eliminating the disposal of spent brightener and rinses. Cost savings will result from the avoided purchase of brightener and reduced disposal costs. It should be noted that the caustic bath, a rinse, and the sealant will still be required.*	*Waste reduction = 9,960 gal* *Cost reduction = $3,950/yr* *Implementation cost = $5,000* *Simple payback = 1.3 yr*

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