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EPA ENVIRONMENTAL RESEARCH BRIEF

Waste Minimization Assessment for a Manufacturer of Chemicals

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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 waste but who lack the expertise to do so. In an effort to assist these manufacturers, 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 the University of Tennessee performed an assessment at a plant manufacturing acrylic emulsions, low molecular weight resins, herbicides, and specialty chemicals–approximately 300 million lb/yr. In general, monomers, additives, activators, and catalysts are metered and mixed in tanks then pumped sequentially into reactor vessels. Once the product is formed, the solution is pumped into a blend tank where more chemicals, such as binders, emulsifiers, and thickeners, are added. From the blend tank the product is passed through filters for clump removal then pumped into either storage tanks or drums for shipping. The team's report, detailing findings and recommendations, indicated that the majority of waste was generated in the wastewater treatment system and that the greatest savings could be obtained by installing a natural gas-fired dry-off oven in the wastewater treatment system to reduce (by 81%) the amount of sludge removed to the landfill.

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. This brief provides only summary information and is not intended for use as a thorough analysis. A fully documented report of the same title is available from the authors.

Introduction

The amount of 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 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 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 the University of Tennessee's (Knoxville) WMAC. The assessment teams have considerable direct experience with process operations in manufacturing plants and also have the knowledge and skills needed to minimize 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 and reduction of waste treatment and disposal costs for participating plants. In addition, the project provides valuable experience for graduate and undergraduate students who participate in the program and a cleaner environment without more regulations and higher costs for manufacturers.

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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 waste in the plant and identifies the current disposal or treatment methods and their associated costs. They then identify and analyze a variety of 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 acrylic emulsions, low molecular weight resins, herbicides, and other specialty chemicals. The plant operates 8,400 hr/yr to produce approximately 300 million pounds of chemicals.

Manufacturing Process

The processes are complex and vary extensively in the exact methods used in order to produce the final product. The production of one particular low molecular weight dispersant product generates significant quantities of wastes and therefore will be considered a separate process in this evaluation. The process lines are described below in detail.

Acrylic Emulsion Production

Approximately 400 different acrylic emulsion formulations are produced by this plant. The actual sequence of steps required varies greatly from product to product. However, the overall process sequence is similar in most cases and is described below. Raw materials for the emulsion line include monomers, additives, activators, and catalysts in either liquid or solid form. Some monomers have been pre-mixed with inhibitors for stabilization. Catalysts are used to activate the monomers and initiate the desired reactions. Activators increase the activity level of the catalysts and allow reactions to overcome the effects of the inhibitors. Additives include detergents, dispersants, and pH-adjustment ingredients.

Monomers are pumped from tanker trucks to monomer tanks for storage. From the storage tanks, monomers are pumped to holding/premixing tanks, and in some cases to the additive, activator, and catalyst holding tanks where mixing occurs. The additives, activators, and catalysts may be added directly to the reactors without being mixed with monomers in their respective holding tanks.

From the holding tanks, raw materials are mixed together using certain proprietary recipes in one of three temperature- and pressure-regulated reactors where polymers are formed. Chemical reactions are initiated by addition of catalysts and are regulated with additives or by pressure and temperature adjustment.

Next, the resulting acrylic emulsion polymers are pumped to blend tanks where other ingredients are added. At this point approximately 40% to 60% of the emulsion is water. Formaldehyde is added as a preservative to control bacteria and mold growth, and ammonia is added to approximately half of the product for pH adjustment. Another pH-adjustment chemical that is added in the blend tanks is sodium hydroxide. Other ingredients such as emulsions, emulsifiers, surfactants, binders, and thickeners are added to modify monomer viscosity, to stabilize the polymers, and to hold the polymers in suspension. De-ionized water is added to lower the solids content. After each polymer batch is processed, the blend tanks are flushed with de-ionized water that is then pumped to the plant's wastewater treatment system.

Wastes generated up to this point in the process include composited absorbed monomers, burnable liquids, and off-grade methylolacrylamide/acrylamide. Most of the composited absorbed monomer waste generated occurs from spillage during loading and unloading of the railcars or from batch spills and reactor clean-ups. Burnable liquids waste results from off-spec mixtures or reactions resulting from incorrect temperatures or incorrect batch weights of solutions in the feed tanks and reactors. Some of the burnable liquids waste from the off-spec batches are recovered and mixed with good batches. Off-grade methylolacrylamide/acrylamide results from bad batches of a particular commercial product. In addition, some waste is generated because of a product's relatively short shelf life. Equipment and/or operator error also accounts for a portion of off-grade material.

From the blend tanks, the acrylic emulsion polymers are pumped through tightly woven cloth filters that separate unwanted clumps of product from the water phase. The used filters, which contain clumps of product, are shipped offsite to a landfill. (An estimated 0.25% of actual product is trapped in the filters.) After filtering, the emulsions are pumped either to storage tanks or directly into drums for shipping.

Low Molecular Weight Resin Production

Production processes and raw materials for the low molecular weight (LMW) resins are identical to those of the acrylic emulsions until the product is pumped into the blend tanks.

Following batch polymerization in the reactor vessels, the LMW resin product is pumped to one of six blend tanks where different additives including water, sodium hydroxide, ammonia, detergents, and emulsifiers are added. These additives provide pH adjustment, solids adjustment, and preservation of the product. From the blend tanks, the LMW resin polymers are pumped either to storage tanks for future shipping or directly to drums for immediate shipping.

One waste generated from this production line is an unsalable product, which is shipped offsite as a hazardous waste. Additional waste generated by this line is a result of off-grade batches.

Other wastes generated in this process are similar to those in the emulsion line and include composited absorbed monomers, burnable liquids, and off-grade methylolacrylamide/acrylamide. These wastes are generated in the same manner mentioned above. An abbreviated flow diagram for acrylic emulsion and the LMW resin process is shown in Figure 1.

Dispersant Process

The production of one particular low molecular weight resin product (a proprietary dispersant) results in the generation of two significant waste streams and will be considered here as a separate process description.

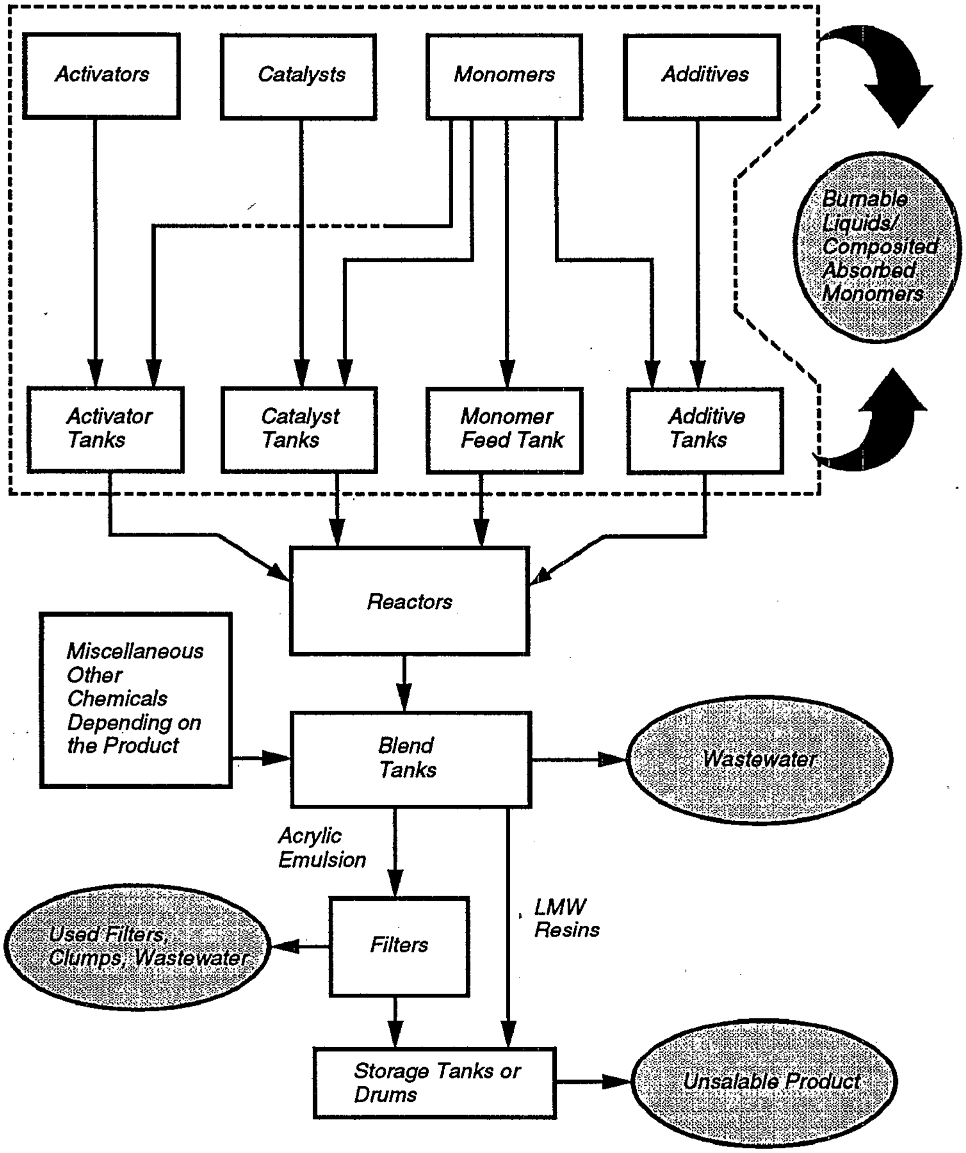

Figure 1. *Abbreviated flow diagram for the acrylic emulsion and LMW resin process.*

Xylene, diisobutylene (DIB), and other monomers and additives are pumped to the reactors in the LMW resin production line. In a batch production, polymers are formed in the reactors. The product is pumped to a separation tank where the unwanted heavier DIB settles to the bottom of the tank and the lighter-fraction product is decanted from the top. An emulsion-like interface composed of DIB and product is formed between the product and the DIB layers and is removed from the tank and shipped offsite as a hazardous waste. Some of the DIB solvent from the separation tank is drained to a storage tank where further separation by settling occurs. Product/DIB interface is removed from this storage tank and is shipped offsite as hazardous waste. The DIB wet solvent from this tank is pumped to the boiler and burned. Recovered xylene/DIB mixture from the separation tank is returned to the reactor.

From the separation tank, the upper layer product fraction is decanted into another separation tank. Water is separated from the product and pumped to the plant's water treatment system. The product is pumped to a blend tank from which more DIB wet solvent is removed and burned in the boiler. The product is then pumped either to storage tanks or to drums for shipping. An abbreviated flow diagram for the dispersant process is shown in Figure 2.

Herbicide/Specialty Chemical Production

Ingredients are mixed together in a pressure- and temperature-regulated reactor where a specified reaction occurs. Absorbed propionic acid waste is generated from the loading and unloading of material. High- and low-acidic content propionic acid wastes are generated by the reactions. Highly acidic propionic

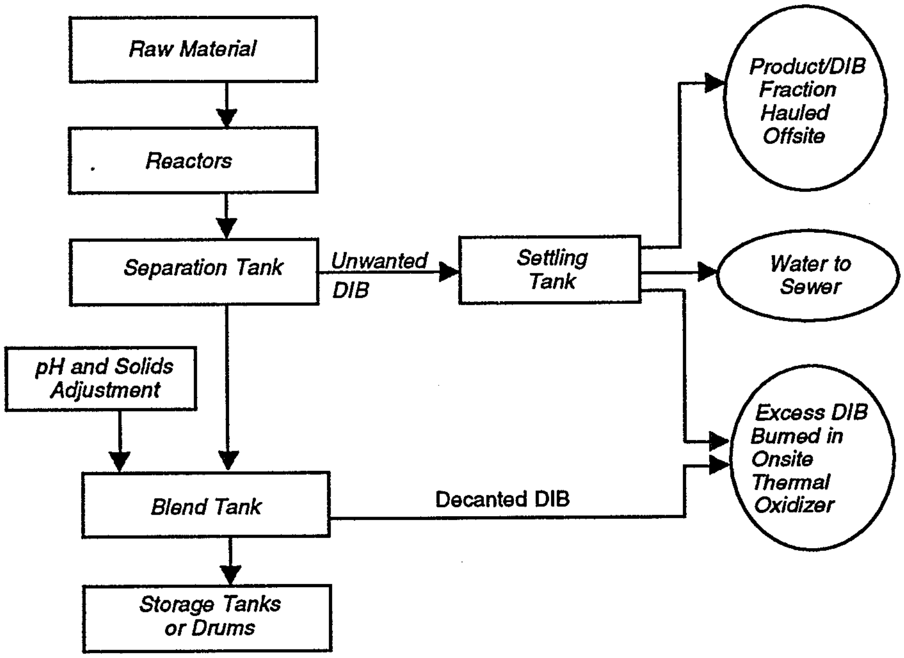

Figure 2. Abbreviated flow diagram for the dispersant process.

acid is recycled back into the reactors for use in further processing. The low-acidic content propionic acid is pumped to the wastewater treatment system where it is used to neutralize caustic wastewater from other plant operations.

From the reactor, the product is pumped to a blend tank to which other chemicals and emulsifiers are added; these substances reduce the viscosity of the product. Several wastes are generated from the annual cleaning of the reactor and blend tank including wastewater that is pumped to the wastewater treatment system, herbicide residue, and herbicide articles (contaminated employee clothing). From the blend tank, the products are loaded onto railcars and shipped. An abbreviated flow diagram for the herbicide/specialty chemical process is shown in Figure 3.

Pollution Abatement (PA) System

This plant uses a pollution abatement system to remove vapors from various areas of the plant including the monomer storage area, tanks in the resin production area, and the reactors and holding/premixing tanks in the emulsion production line. This system was installed mainly to remove vapors with persistent irritating odor from the plant.

A blower located down the line creates a pressure difference and pulls fresh air over the tanks mentioned above. Vapors collected from the monomer storage area and resin area tanks are blown to separate liquid knock-out tanks. These tanks act as condensers and use ambient air cooling to condense a portion of the vapors. The resulting condensate from these tanks is directed to the water treatment facility. From the knock-out tanks, the vapors are ducted through separate lower explosive limit (LEL) monitors that evaluate the flammability of the vapors. From the monitors, the vapors are directed through backfire preventers that act as safety valves and prevent vapors from being drawn back through the system.

Vapors from the reactors and feed tanks in the emulsion line follow a similar route through the PA system; however, they are first ducted through a caustic scrubber. Caustic solution is added to this scrubber as well as 150 gal/min of water to remove particulates from the fumes. This solution is dumped to the water treatment system every 11 days. The vapors are then directed through a liquid knock-out tank (from which water is pumped to water treatment), through a backfire preventer, and then through an LEL monitor.

From that monitor, the vapors pass through a blower, another backfire preventer, and finally most of the vapors (99.97%) enter a natural gas-fired thermal oxidizer at 1400°F.

Wastewater Treatment System

Another onsite waste treatment facility this plant has installed is its wastewater treatment system. Wastewater from the emulsion line and the resin line, laboratory wastewater, and air compressor and other cooling water are directed to this facility for treatment. All incoming water passes through a roto-strainer that removes suspended solid particulates. The solid waste falls into two hoppers and is eventually hauled offsite to a landfill.

From the roto-strainer, the water enters a neutralization tank where carbon dioxide and low acidic propionic acid from the herbicide line are added for neutralization. The water then enters a second neutralization tank where the water is agitated to promote further neutralization. Next, the wastewater enters three open-air mixing basins in which sludge is allowed to settle to the bottom. Sludge is removed quarterly to landfill.

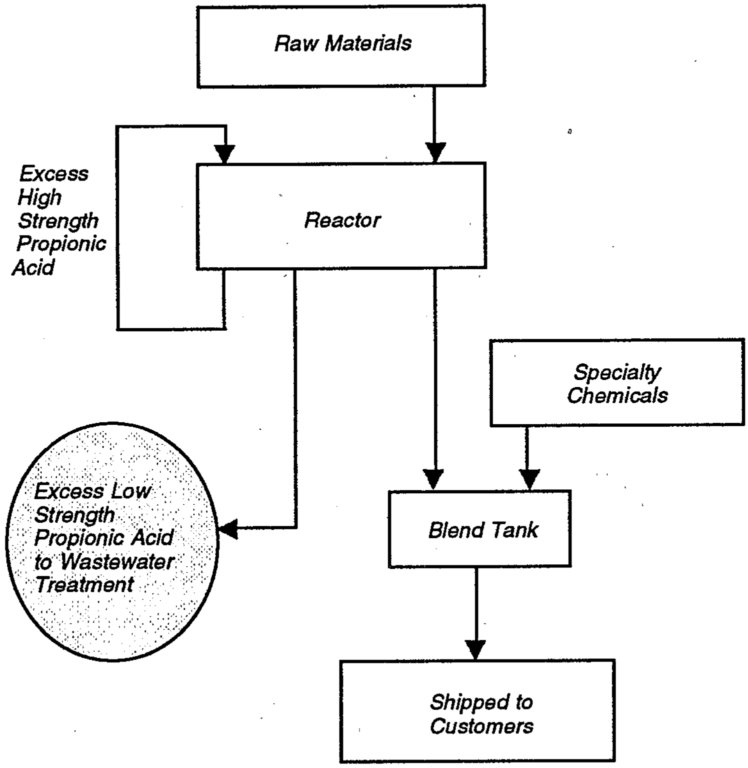

Figure 3. *Abbreviated flow diagram for the herbicide/speciality chemical process.*

The effluent wastewater is released to the municipal sewer. Total water discharged from the plant on an annual basis is approximately 126 million gal/yr.

Existing Waste Management Practices

- A pollution abatement system removes noxious and odorous vapors from the plant and incinerates them.
- Off-grade monomers and polymers are reused in an effort to produce salable products.
- Diisobutylene wet solvent is burned in an onsite boiler.

Waste Minimization Opportunities

The type of waste currently generated by the plant, the source of the waste, the quantity of the waste, and the annual treatment and disposal costs are given in Table 1.

Table 2 shows the opportunities for waste minimization that the WMAC team recommended for the plant. The type of waste, the minimization opportunity, the possible waste reduction and associated savings, and the implementation cost along with the payback time are given in the table. The quantities of waste currently generated by the plant and possible waste reduction depend on the production level of the plant. All values should be considered in that context.

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 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 Waste Generation

Waste Generated	Source of Waste	Annual Quantity Generated	Annual Waste Management Cost ($)
Burnable liquids	*Off-grade mixtures and bad reactions in the acrylic emulsion and low molecular weight resin production lines.*	*15,400 lb*	*77,110*
Composited absorbed monomers	*Spillage and clean-up of reactors in the acrylic emulsion and low molecular weight resin production lines.*	*15,400 lb*	*77,110*
Off-grade methylolacrylamide/ acrylamide	*Off-grade batches of product in the acrylic emulsion and low molecular weight resin production lines*	*5,100 lb*	*40,760*
Used filters and trapped product	*Filtering process in the acrylic emulsion production line.*	*44,800 lb*	*33,080*
Unsalable low molecular weight resins	*Expired products and off-grade batches of products in the low molecular weight resin production line.*	*20,880 lb*	*116,200*
Diisobutylene (DIB) wet solvent	*Spent solvent from the dispersant production line. DIB wet solvent is sent to an onsite thermal oxidizer.*	*316,220 lb*	*24,500*
Product/DIB interface	*Separation tank in the dispersant production line.*	*25,750 lb*	*79,860*
Absorbed propionic acid	*Spillage in the herbicide/specialty chemical production line.*	*6,000 lb*	*13,510*
Contaminated employee clothing	*Herbicide/specialty chemical production line.*	*	*
Herbicide residue	*Cleaning of the reactor and blend tank in the herbicide/specialty chemical production line.*	*1,000 lb*	*24,150*
Cold stack gases (noxious, odorous, and organic vapors drawn from monomer storage area, tanks in resin line, and resin reactors and tanks)	*Thermal oxidizer and heat exchanger in the Pollution Abatement System.*	*394,200 ft^3*	*0***
Wastewater sludge	*Onsite wastewater treatment system.*	*300,000 lb*	*456,800*
Wastewater	*Onsite wastewater treatment system.*	*126,000,000 gal*	*2,121,700*

**New waste; no data available.*

***There are no direct costs reported for handling evaporative waste.*

Table 2. Summary of Waste Minimization Opportunities

Waste Generated	*Minimization Opportunity*	*Annual Waste Reduction*		*Net Annual Savings ($)*	*Implementation Cost ($)*	*Payback Years*
		Quantity	*Percent*			
Burnable liquids	*Upgrade the redundant sensing and control devices on the reactor raw material lines to reduce the amount of off-specification product batches.*	*11,550 lb*	*75*	*139,810*	*365,480*	*2.6*
Composited absorbed monomers		*2,890 lb*	*19*			
Off-grade methylolacrylamide/ acrylamide		*3,480 lb*	*71*			
Unsalable product		*3,130 lb*	*15*			
Wastewater sludge	*Install a natural gas-fired dry-off oven in the wastewater treatment system to reduce the amount of sludge removed to the landfill.*	*244,030 lb*	*81*	*92,730*	*70,320*	*0.8*

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