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ENVIRONMENTAL RESEARCH BRIEF

Waste Reduction Activities and Options for a Manufacturer of Fine Chemicals Using Batch Processes

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Abstract

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey. One of the sites selected was a manufacturer of fine chemicals using batch processes. A site visit was made in 1990 during which several opportunities for waste minimization were identified. Options identified for waste reduction included initiation of solvent recycling or reconditioning for reuse and modifying the chemical reaction conditions to improve product quality and reduce the amount of reprocessing which has been necessary. Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

Introduction

The environmental issues facing industry today have expanded considerably beyond traditional concerns. Wastewater, air emissions, potential soil and groundwater contamination, solid waste disposal, and employee health and safety have become increasingly important concerns. The management and disposal of hazardous substances, including both process-related wastes and residues from waste treatment, receive significant attention because of regulation and economics.

As environmental issues have become more complex, the strategies for waste management and control have become more systematic and integrated. The positive role of waste minimization and pollution prevention within industrial operations at each stage of product life is recognized throughout the world. An ideal goal is to manufacture products while generating the least amount of waste possible.

The Hazardous Waste Advisement Program (HWAP) of the Division of Hazardous Waste Management, NJDEPE, is pursuing the goals of waste minimization awareness and program implementation in the state. HWAP, with the help of an EPA grant from the Risk Reduction Engineering Laboratory, conducted an Assessment of Reduction and Recycling Opportunities for Hazardous Waste (ARROW) project. ARROW was designed to assess waste minimization potential across a broad range of New Jersey industries. The project targeted 30 sites to perform waste minimization assessments following the approach outlined in EPA's *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003). Under contract to NJDEPE, the Hazardous Substance Management Research Center at the New Jersey Institute of Technology (NJIT) assisted in conducting the assessments. This research brief presents an assessment of the manufacturing of fine chemicals using batch processes (1 of the 30 assessments performed) and provides recommendations for waste minimization options resulting from the assessment.

Methodology of Assessments

The assessment process was coordinated by a team of technical staff from NJIT with experience in process operations, basic chemistry, and environmental concerns and needs. Because the EPA waste minimization manual is designed to be primarily applied by the inhouse staff of the facility, the degree of involvement of the NJIT team varied according to the ease with which the facility staff could apply the manual. In some cases, NJIT's role was to provide advice. In others, NJIT conducted essentially the entire evaluation.

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The goal of the project was to encourage participation in the assessment process by management and staff at the facility. To do this, the participants were encouraged to proceed through the organizational steps outlined in the manual. These steps can be summarized as follows:

- Obtaining corporate commitment to a waste minimization initiative
- Organizing a task force or similar group to carry out the assessment
- Developing a policy statement regarding waste minimization for issuance by corporate management
- Establishing tentative waste reduction goals to be achieved by the program
- Identifying waste-generating sites and processes
- Conducting a detailed site inspection
- Developing a list of options which may lead to the waste reduction goal
- Formally analyzing the feasibility of the various options
- Measuring the effectiveness of the options and continuing the assessment.

Not every facility was able to follow these steps as presented. In each case, however, the identification of waste-generating sites and processes, detailed site inspections, and development of options was carried out. Frequently, it was necessary for a high degree of involvement by NJIT to accomplish these steps. Two common reasons for needing outside participation were a shortage of technical staff within the company and a need to develop an agenda for technical action before corporate commitment and policy statements could be obtained.

It was not a goal of the ARROW project to participate in the feasibility analysis or implementation steps. However, NJIT offered to provide advice for feasibility analysis if requested.

In each case, the NJIT team made several site visits to the facility. Initially, visits were made to explain the EPA manual and to encourage the facility through the organizational stages. If delays and complications developed, the team offered assistance in the technical review, inspections, and option development.

No sampling or laboratory analysis was undertaken as part of these assessments.

Facility Background

The facility is an integrated chemical production installation which is part of the manufacturing capability of a large chemical production company. The facility which participated in this study houses pilot plant activities for fine chemicals and for chemical intermediates under investigation by the company. In addition, some manufacturing of products, particularly low volume products occurs at this facility. The facility also hosts research activities, packaging operations, and Quality Assurance laboratory activities. The site is approximately 50 years old, although most of the buildings are significantly newer. The equipment in use varies from brand new to over 30 years in age.

Manufacturing Processes

Although many independent operations take place at this installation, it was decided to focus this initial effort on one of the smaller manufacturing operations. Such a focus was expected to provide the technical and operating management of the facility an illustration of the assessment process and provide the information necessary to plan a larger scale assessment process for the entire facility. It was desirable, therefore, to select a discrete process which could be thoroughly analyzed and which held potential for measurable and significant pollution prevention opportunities.

The process investigated uses relatively uncomplicated chemistry requiring formation of a coordination-type complex between an organic amine and a volatile halogen-containing solvent. The complexation is carried out in the presence of a small amount of an alcohol co-solvent. The individual components are synthesized either offsite or in an area separate from the complexation equipment and process. The process involved is a relatively simple three component mixing and complexation reaction which allows for an in-depth analysis of waste streams and consideration of alternatives.

Typical steps in the manufacturing process include the following activities:

- A concentrated solution of the organic amine in an alcohol solvent is slowly added to a large volume of vigorously agitated halogen-containing solvent.
- As a result of the mixing, a portion of the resulting amine/solvent complex precipitates.
- The product yield is increased by distilling off a portion of the halogen-containing solvent in order to induce crystallization of the product complex.
- The product is recovered by filtration by vacuum.
- Recovered solvent is sent offsite for recycling.

Existing Waste Management Activities

The company has already recognized the advantages and benefits of identifying and implementing waste reduction and pollution prevention practices. The current procedure which utilizes offsite recycling for the waste streams from the investigated process illustrates that recognition and commitment.

Waste Minimization Opportunities

For this facility, the initial use of the manual was carried out by the staff of the facility. The NJIT team participated in identification of some of the options for waste reduction. During the assessment process, the following waste streams were identified:

- Liquid Solvent Stream
- Vapor Losses

The liquid solvent waste stream results from distillation of solvent to raise the product concentration to induce crystallization and from the recovery of the product by filtration. It has been generated at a rate of about 19,000 kg/yr. The waste stream has been managed by offsite recycling at an annual cost of about $12,000.

The vapor loss stream results from atmospheric losses during the solvent transfer to a receiving vessel. A minor portion of the loss has been estimated to result from leaking connections and escape during vessel openings. More of the vapor loss results from the vacuum filtration step which is used to recover the solid product. A portion of the volatile solvent is lost through the vacuum system and is not easily recovered. It is estimated that about 1200 kg of the mixed solvents are lost annually through these routes. The fraction which is captured is sent offsite for recycling at an annual cost of about $500.

The continuing technical challenge is to reduce further the size of the two waste streams resulting from the process. Technically, it may be easier to reduce the amount of vapor loss by tighter vapor handling practices. Because the volume of the liquid solvent stream is greater, there may be greater opportunities there for high percentage reduction.

From the perspective of pollution prevention, the company may desire to look for options which reduce emissions to the atmosphere, reduce the total amount of chemical usage, encourage onsite recycling or reuse of the materials, or allow use of less hazardous substances in the manufacture and processing of the product. However, it was decided that the performance requirements for the product precluded any changes in the chemistry of the process until a detailed product characterization and performance evaluation could be carried out. Therefore, any changes in the actual substances used to manufacture the product could not be considered to be a viable initial pollution prevention option. Rather, both of the two waste streams were considered individually to identify the reasons for the size of the streams and possible modification of practices which had potential for their reduction.

The liquid solvent stream presented the greatest challenge in terms of volume. The relatively high cost of the solvents/reactants in the process had previously led to consideration of alternative ratios of materials in order to minimize solvent use. The existing process used the minimum volumes required in order to achieve the necessary performance for the product.

The solvent waste stream is sent offsite for recycling because the combination of alcohol co-solvent with the halogen-containing solvent presents some complications with the distillation process which would normally be used for solvent purification. The necessary equipment to carry out this purification does not exist at the site and the relatively small volume of this stream does not justify investment in such equipment at this time. The required distillation equipment does exist at another company-owned site, however, so one of the options identified is to move this process to another company location in order to permit onsite recovery, recycling and reuse of the solvent.

An alternative to this option was also identified which would utilize a two-step purification of the solvent system. The concept proposed was to utilize an adsorbent for the alcohol component which, in a packed bed medium, could selectively remove the alcohol leaving the halogen-containing solvent in a more easily purified state allowing distillation with existing equipment at the site. Alternatively, it may be possible to reuse the halogen-containing solvent directly although this would have to be verified by product quality and performance testing. An appropriate choice of alcohol adsorbent could allow regeneration with recovery and reuse of the alcohol. Such a procedure would be expected to reduce substantially the percentage of this waste stream which needs to be sent for treatment.

Another alternative option addressed the issue of reduction of the volume of raw materials used in the process itself. Although, as indicated previously, it would not be possible to implement a new process using smaller quantities of the materials, examination of the production records indicated that about 10% of the batch runs represented reworking of batches which failed quality standards. Stated another way, this means that a savings of 10% of the waste stream could be realized by identifying and correcting the reasons for the below standard quality of these batches. It was determined that the product complex which is formed is sensitive to the presence of water. In fact, moisture can cause the decomposition of the complex. The presence of high humidity during the complexation process was determined to be the primary cause of the 10% failure rate. It was proposed, therefore, to provide a more controlled temperature/humidity environment for the manufacturing process to eliminate the failures of these batches. An alternative suggestion was to avoid scheduling production runs during times of the year when ambient humidity would be expected to be high.

The vapor loss waste stream presented some additional challenges. As indicated previously, two significant sources for such losses were identified—fugitive emissions and the filtration step in the product recovery phase of the process. These two sources lead to suggestions of different types of options for reduction of vapor loss.

Several applications of modified engineering practices were identified for reduction of fugitive losses. These included improved control over condenser temperature and reaction temperature, use of couplings and connectors with low dead volume, regular inspection and replacement when necessary of seals, valves, and pressure relief devices. Modified practices such as gravity-induced introduction of solvents rather than by pumping to reduce any pressure buildup in the reaction vessel were also suggested.

While it may be difficult to quantify the pollution prevention impact of options such as these, it is clear that they have the potential for reducing fugitive emission.

Addressing the issue of vapor losses during the filtration process required identification of different options. It was determined that the losses occurred because the relatively low-boiling solvent vaporized under the vacuum filtration conditions and was lost through the vacuum system. The option identified to reduce such losses was to utilize existing equipment to carry out pressure filtrations instead of vacuum filtration. The same pressure drop across the filter could be achieved, but because the absolute pressure in the system was higher, volatilization could be reduced substantially. Therefore, solvent loss would be reduced.

The type of waste currently generated by the facility, 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 recommended for the facility. 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 at the facility and possible waste reduction depend on the level of activity of the facility.

It should be noted that the economic savings of the minimization opportunity, in most cases, results from the need for less raw material and from reduced present and future costs associated with waste treatment and disposal. 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 savings that would result when the opportunities are implemented in a package.

Regulatory Implications

An important regulatory implication in this study is that although the majority of the waste stream from this process is recycled, it is sent offsite for purification and reuse. Therefore, the streams are classified as waste. Even though the company has at a nearby site the technical capability to purify the material and return it to the original process, regulatory barriers prevent the ready implementation of this practice. The regulatory issue is that because the two facilities are considered separately from a regulatory point of view, the material would have to be sent from this facility under a hazardous waste manifest. Then even after purification it would still be considered hazardous waste unless the company went through a process to have it delisted. Even then, the company would be seen as using a

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"hazardous waste" in the manufacture of its products. The company is not willing to argue against this type of public perception.

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

Table 1. *Summary of Current Waste Generation*

Waste Generated	*Source of Waste*	*Annual Quantity Generated*	*Annual Waste Management Costs*
Liquid Solvent Stream	*Solvent distillation*	*19,000 kg*	*$12,000*
Filtrate	*Filtration of solid product*	*1,200 kg*	*500*
Vapor Loss	*Fugitive emissions*	*variable—at least 1000 kg*	*500*

Table 2. *Summary of Recommended Waste Minimization Opportunities*

Waste Stream Reduced	*Minimization Opportunity*	*Annual Waste Reduction*		*Net Annual Savings*	*Implementation Cost*	*Payback Years* *
		Quantity	*Percent*			
Liquid Solvent Stream	*Purify onsite for recycling by straight distillation*	*18,000 kg*	*94*	*$16,500*	*$120,000*	*7.3*
	Move process to other facility where distillation equipment already exists	*18,000 kg*	*94*	*16,500*	*200,000*	*12.1*
	Reduce frequency of product rework by controlling ambient humidity	*1900 kg*	*10*	*1,750*	*2,000*	*1.1*
Vapor Loss	*Change from vacuum filtration to pressure*	*1,000 kg*	*84*	*500*	*0 existing*	*0*
Vapor Loss Fugitive Emissions	*Introduce various techniques such as improved condenser and reaction temperature control, regular inspection for leaks, and introduction of solvents by gravity instead of pressure*	*800 kg*	*80*	*400*	*500*	*1.2*

* Savings result from reduced raw material and treatment and disposal costs when implementing each minimization opportunity independently.

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