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AVOIDING SITE CONTAMINATION BY WASTE MINIMATION*

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Summary

This paper presents a systematic discussion of the hierarchy of methods available for reducing or eliminating the volume or toxicity of waste that must be disposed by a manufacturing facility. This is done by examining the life cycle of waste starting from the point of generation to its ultimate disposal. Of particular importance for avoiding chemical plant site contamination is the prevention of waste generation at the source. Methods include: product reformulation, process modification, redesign of equipment, housekeeping and segregation. Case histories of 3M Company projects and programs are used as examples of how waste can be minimized or eliminated at various stages in the waste life cycle with emphasis on source reduction.

Introduction

Although a few people and organizations have been involved in and have actively promoted pollution prevention programs for some time, widespread activity did not really get under way in the United States until 1984 when Congress passed amendments to the Resource Conservation and Recovery Act (RCRA) declaring waste minimization to be national policy. These amendments are known as the Hazardous and Solid Waste Amendments of 1984 (HSWA).

Section 1003(b) of HSWA states:

> The Congress hereby declares it to be the national policy of the United States that, wherever feasible, the generation of hazardous waste is to be reduced or eliminated as expeditiously as possible.

As a part of implementing this policy, the Act calls for all generators of hazardous waste to include signed statements on all hazardous waste manifests certifying that the generator has a program in place to reduce the volume and toxicity of waste generated to the degree the generator has determined to be economically practicable. The Act further requires all generators to submit biennial reports that include: (a) a description of the efforts undertaken dur-

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ing the reporting period to reduce the volume and toxicity of the waste generated and (b) a listing of reductions in toxicity and volume that were achieved.

This legislation has, understandably, created a flurry of activity in the area of waste minimization the past few years. Government agencies such as the U.S. Environmental Protection Agency (EPA) and the Congressional Office of Technical Assessment (OTA) have issued reports on the subject. Citizen environmental activist groups have been devoting their energies and resources to promoting the concept. Professional organizations and industrial trade associations have been sponsoring workshops and seminars. Consultants and equipment manufacturers are directing marketing efforts towards waste minimization. There is also a rush of articles and new books being published on waste minimization technologies and programs.

It is the purpose of this paper to present a broad and comprehensive perspective of waste minimization. Discussion is based on the concept of protecting the receptor (land) as called for by the HSWA. While examples of source reduction are emphasized, other waste minimization practices are included to demonstrate the full potential for waste minimization in the area of environmental protection.

Life cycle concept

The model of waste minimization presented here can be likened to the well established and successful model of communicable disease control that is so familiar to those of us with public health backgrounds. In this model, communicable diseases can be controlled or prevented by taking steps to control the source, the mode of transmission or the susceptibility of the receptor. The analogous parts for the waste minimization model are the source, handling procedures and land disposal. Although any one disease can be controlled by controlling just one of the three "links" in the chain, it is better to attack all three simultaneously. The number and types of methods used to attack each link will vary and should be selected according to their technical and economic feasibility. Professional judgment must be used to obtain the maximum return for the effort expended. The very same is true when considering the analogous waste minimization model when applied to a particular waste. It is also important to keep in mind that the best combination of waste minimization measures for any waste can change from time to time and from place to place depending on prevailing circumstances.

The waste minimization "life cycle" model is depicted in Fig. 1. The waste has its "birth" in the source and its "life" is pictured as the handling between birth and final disposal in or on the land.

When waste minimization is considered only as a form of control at the source, many opportunities are lost in the life portion of the cycle as shown in the figures that follow. Figure 2 shows the amount of waste going to the land

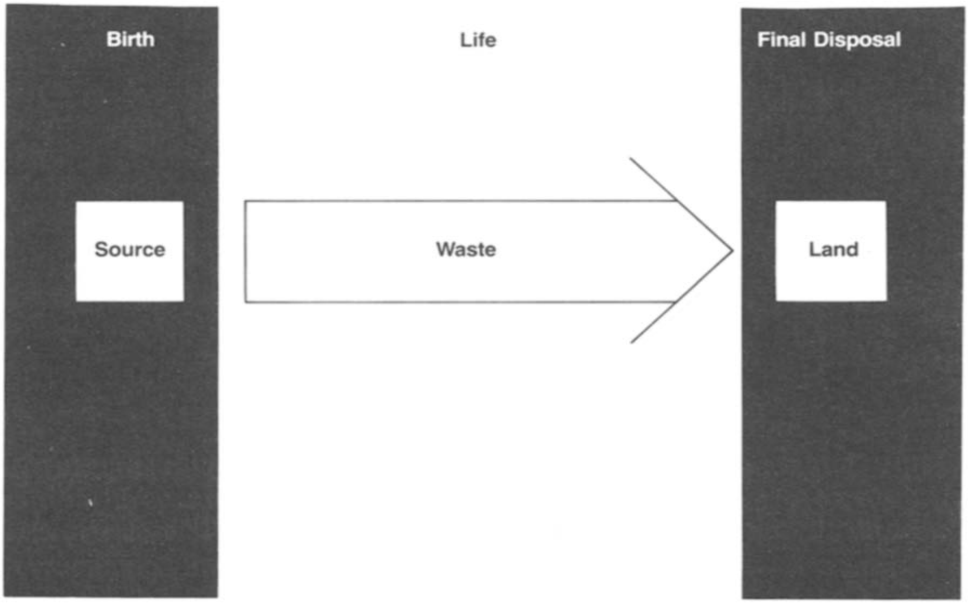

Fig. 1. Waste life cycle without waste minimization.

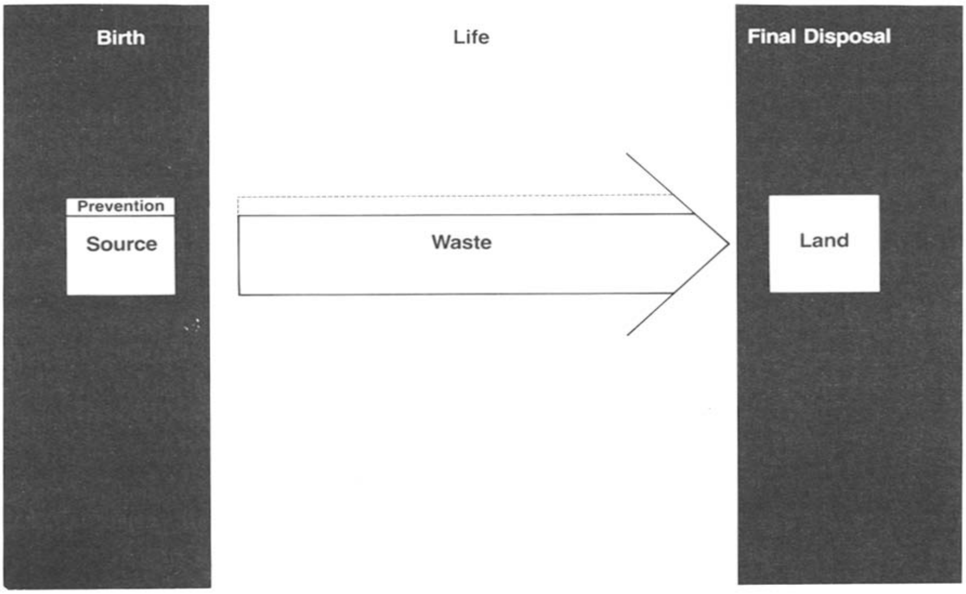

Fig. 2. Effect of source prevention on the quantity of waste requiring ultimate disposal.

for disposal can indeed be reduced by preventing its creation in the first place but Fig. 3 shows that the amount can be reduced further by reclaim and recycle on site. This can be reuse of the waste with or without reprocessing, either back

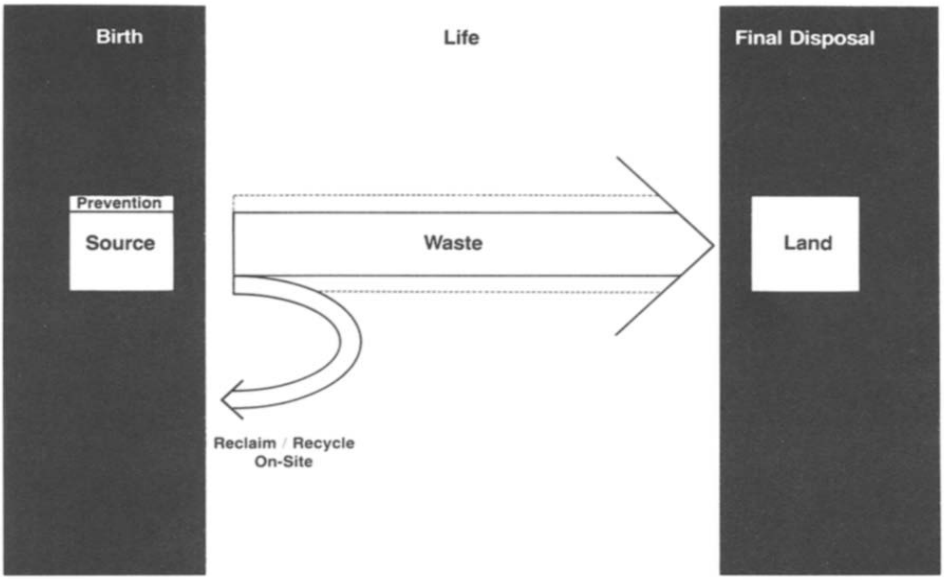

Fig. 3. Combined effect of source prevention and on-site reclaim and recycle on the quantity of waste requiring ultimate disposal.

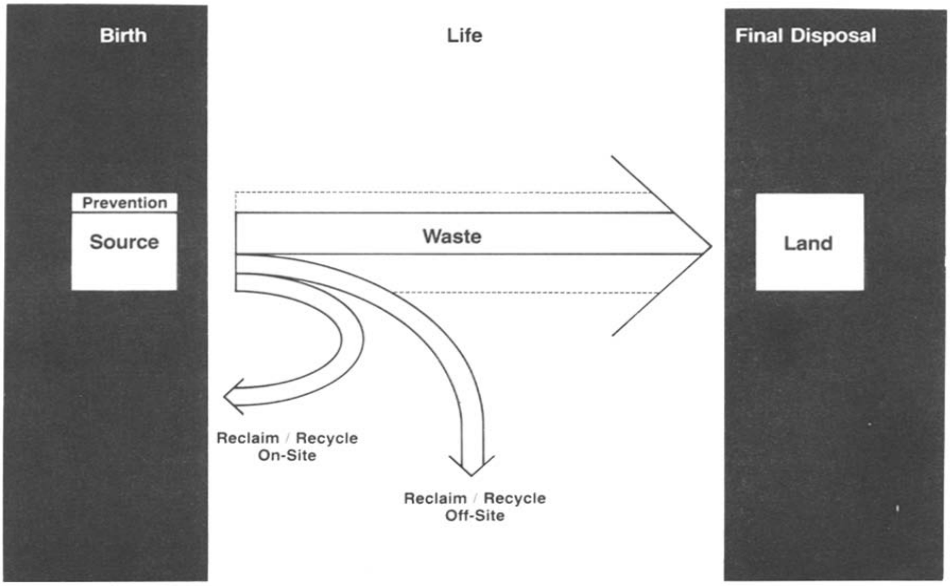

Fig. 4. Combined effect of source prevention and on-site and off-site reclaim and recycle on the quantity of waste requiring ultimate disposal.

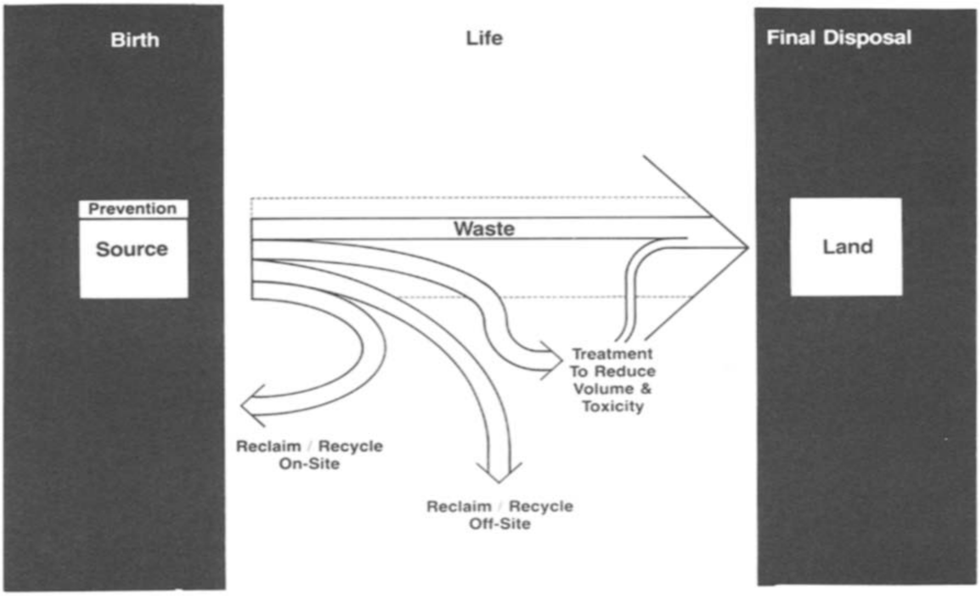

Fig. 5. Combined effect of source prevention, on-site and off-site reclaim and recycle, and treatment on the quantity of waste requiring ultimate disposal.

into the same process from which it came or into some other process. Figure 4 shows that the amount of waste going to the land for disposal can be reduced still further by reclamation and recycling off-site. There are many options here. The waste can be reused with or without reprocessing and any reprocessing can be done either on or off the site where the waste is generated. The number of potential uses is also expanded since the choice is not limited to just those available on the site of generation. Finally, as shown in Fig. 5, the amount and toxicity of waste going to land for ultimate disposal can be minimized and sometimes even eliminated by appropriate treatment such as incineration.

The balance of this paper presents specific examples of how waste streams at 3M company have been reduced or eliminated by applying the life cycle concept. These examples have been categorized for easy reference and include prevention at the source, on-site reclaim/recycle, off-site reclaim/recycle, treatment to reduce volume and/or toxicity, and some advanced waste minimization techniques.

Specific examples

A. Prevention at the source

1. Product reformulation

a. Two metal catalysts needed to make static control mats used under personal computers caused process waste to be classified RCRA hazardous. Non-

hazardous substitutes for these chemicals were found and their use adopted thereby eliminating the generation of several tons per year of hazardous waste.
b. Many 3M products that originally had to be made using solvent based coating solutions have been reformulated to use water based coating solutions. The scrap coating materials and cleanup wastes from making these products are no longer classified as RCRA hazardous.
c. Several 3M products, such as tape, are coated with pressure sensitive adhesive. In some cases, hot melt adhesive is being substituted for solvent based adhesive. As with water based coating solutions, the scrap coating materials and cleanup wastes from applying the adhesive to these products are no longer classified as RCRA hazardous.

2. Process modification

a. Copper sheeting must be thoroughly cleaned before it can be used for making electronic products. Formerly, the sheet was sprayed with ammonium persulfate, phosphoric acid and sulfuric acid. This created a hazardous waste that required special handling and disposal. That procedure has been replaced by a specially designed new machine with rotating brushes that scrub the copper with pumice. The fine abrasive pumice material leaves a sludge that is not hazardous and can be disposed in a municipal landfill. This process change eliminates the generation of 40000 pounds of hazardous waste per year and saves $15000 per year in raw material disposal costs. The capital cost was $59000.
b. Cleaning kettles at one chemical plant used to require 800 hours of labor and 110 tons of solvent annually. The cleaning process involved filling the kettles with the solvent, stirring the solution with a mixer, draining the kettles and even entry into the kettles by workers to do some hand scraping. Cleaning one kettle took 1 employee 3 hours. A high pressure, rotating spray head is now being used to clean the kettles. Use of this head has greatly reduced the amount of cleaning solution required, has reduced the amount of time required for cleaning the kettles to 10–20 minutes and has improved safety by eliminating the need for workers to enter the kettles. All the solvent is saved for reuse by passing it through a sedimentation tank to remove solids. First year savings were $61500. The capital cost was $69000.
c. Adhesive at one 3M plant used to be made in batches and then transferred into a large storage tank before use. If one batch did not meet the required quality standard, it would often spoil the entire contents of the storage tank. The rejected material contained solvent and would have to be disposed as a RCRA hazardous waste. A technique was developed for rapidly running a quality control test on freshly made batches of adhesives so that they could be tested and either accepted or rejected before being placed into the storage tank. This has reduced the amount of rejected material that must be disposed by approximately 110 tons per year at an annual cost savings of about $207000.

d. An adhesive used in manufacturing sand paper that remained in the coater feed tank at the end of the week used to be sent out for disposal as hazardous waste because there was not way to preserve it over the weekend. A method has been developed for cooling the adhesive, storing it as a solid then reheating it for use on Monday thereby eliminating the need to send it out for disposal. This procedure has prevented the generation of 6 tons per year of RCRA hazardous waste and saves the company approximately $10000 annually.

3. Redesign of equipment

a. A teflon rope packing seal on a product dryer was found to be contributing to contamination problems with a particular product. The packing seal was replaced with a mechanical seal. The new seal reduced contamination of the product thereby reducing the amount of product that had to be sent to waste for disposal. This equipment change led to annual savings of $322000 through increased yields and reduced maintenance and disposal costs.

b. When sampling a particular liquid phenolic resin product using a tap on a process flow line, some of the product had to be wasted before and after the sample was actually collected. A funnel was installed under the sample tap and piping was connected back into the process so that when samples were being taken, no product would be lost. This prevented the generation of about 9 tons of chemical waste per year and saved approximately $22860 annually in increased yield and decreased disposal costs. The capital cost was about $1000.

c. A product coating solution cart was redesigned to eliminate places where solution could become trapped. This change has made it possible to use less solvent when cleaning the cart between coating runs thereby reducing the amount of contaminated solvent that must be disposed. Better cart cleaning has also greatly reduced the manufacture of rejected product. Use of the redesigned cart has eliminated the generation of about 600 pounds of RCRA hazardous waste per year and saves approximately $58000 annually through increased product yield and reduced disposal costs. The capital cost was about $1200.

4. Housekeeping

Dust was being created where a powdered product was being loaded onto and unloaded from a conveyer belt. The dust would settle onto the floor, be swept up and disposed as waste. Containment equipment is being installed to catch the dust so that it can be saved and used as product. This will eliminate the generation of approximately 50000 pounds of waste per year and will result in an annual cost savings of about $150000. The capital cost will be about $340000.

5. Segregation

a. Toxic metal was getting into the wastewater at a 3M plant and contaminating the wastewater treatment plant sludge, rendering it RCRA hazardous.

The source of the metal was traced and a separate treatment system was installed on the process wastestream to prevent the metal from entering the wastewater treatment plant. Even though the toxic metal still has to be disposed, the volume of waste containing that material that must be considered as hazardous has been greatly reduced.

b. The ash at 3M's corporate hazardous waste incinerator must be disposed as hazardous waste. It has been found that magnets can be used to remove nonhazardous ferrous metal from the ash and that the scrap metal can be sold. This procedure reduces the amount of hazardous ash that must be disposed by 50% or 840 tons per year. Significant disposal cost savings are realized as well as about $35000 in revenue from the sale of the scrap metal.

B. On-site reclaim/recycle

1. Direct reuse of waste at source

During the year 1985, 3M plants reclaimed on-site and reused approximately 2680000 gallons of solvent. The following are some examples of how this was done:

a. One 3M plant uses a thin-film evaporator for recovering solvents from scrap adhesive. This reduces by over 80% the 1300 tons per year of rejected adhesive (RCRA hazardous waste) produced by the plant. At the same time, approximately $480000 worth of solvent is reclaimed for reuse.

b. A liquid chemical product requires final filtration. The filter elements must be changed from time to time and when this is done the filter housing must be drained. The chemical product drained from the filter housing used to be rejected and sent out for disposal but now piping has been installed to capture it and return it back into the upstream equipment. About 35 tons of product are recycled back into the process per year and no longer need to be disposed. This produces an annual savings of $37000 per year and only cost $200 for the piping.

c. Several 3M waste solvent streams have been found suitable for use as boiler fuel. At one plant it is planned to use these waste solvents in the boiler on site. This will greatly reduce the amount of waste having to be shipped off-site to a disposal facility and will also reduce fuel costs. In this case, 3000 tons of solvent will be burned per year, producing a net savings in disposal and fuel costs of approximately $630000 annually. Operating costs will about $30000 per year. The total capital cost for boiler modifications, piping, etc. were $330000.

2. Off-site reclaim/on site reuse

In 1985, 3M plants sent approximately 906000 gallons of solvent out to reclaimers to be distilled and returned to the plant of origin for reuse.

C. Off-site reclaim/recycle

1. Some 3M plants are sending waste solvent to other 3M plants for use as boiler fuel. This is particularly true where the plant generating solvent scrap is not burning a liquid fuel or where it would cost too much to install the scrap solvent fuel storage tank, piping and new burner in the boiler.

2. In some cases, it is more profitable to sell waste solvent to a reclaimer for redistillation and sale to a third party. In 1985, 3M plants sold approximately 993000 gallons of scrap solvent for redistillation and resale.

3. Another option is to reprocess waste materials at the point of generation and then sell them directly to another user. The following are some 3M examples:

a. Dust from a rock crushing operation is captured by water scrubbers and the scrubber water is sent to an evaporation pond for disposal. The rock dust settles out and forms a sludge. This sludge has a high salt content due to the concentration of dissolved solids resulting from evaporation of the water. This sludge must be disposed in a controlled industrial waste landfill. It has been found that if the sludge is passed through the plant's rock drying equipment, it changes into a powder that can be captured by existing bag house air filters and packaged. The dried sludge is then sold to another company to be used as a filler in making asphalt roofing shingles. This has eliminated the disposal of 80 tons per year of waste at a savings of approximately $15000. The annual operating cost is about $5000.

b. One 3M plant that redistills and reuses its own solvent has found a unique use for the still bottoms that must be classified as RCRA hazardous. It was discovered that the bottoms in this particular case, if taken to dryness, can be used as a raw material by a nearby cement manufacturing company. This has eliminated the disposal of 295 tons of hazardous waste per year and has provided an annual saving of $127000.

c. Manufacture of magnetic oxides produces an ammonium sulfate that must be disposed. A vapor compression evaporator has been installed to increase the ammonium sulfate concentration of this solution up to about 40 wt.%. This solution is being sold to farmers for use as fertilizer. In this case, the ultimate disposal is still to the land as in the life cycle model but the disposal is being converted to a productive purpose and can be considered as being used as a product by an off-site party. The sale of this fertilizer produces an annual revenue of approximately $150000. The capital cost for the evaporation system and storage facility was $1500000. The operating cost is about $150000.

D. Treatment to reduce volume and/or toxicity

Plants in 3M sent approximately 24300 tons of waste (hazardous and non-hazardous combined) to the corporate incinerator for disposal in 1985. This waste was reduced by 93% to 1700 tons of ash that needed to be disposed as RCRA hazardous waste.

Waste minimization principles are being applied to reduce or eliminate the amount of ash that must be disposed. As mentioned above, the recovery of nonhazardous ferrous scrap metal from this ash reduces the amount of hazardous material that must be disposed by 50%. Methods such as encapsulation to immobilize any heavy metals that may be present are now being investigated for converting the remaining ash into nonhazardous waste.

E. Advanced waste minimization techniques

Waste minimization programs progress in stages as they mature. Initial efforts tend to concentrate on the simple, the obvious, and the inexpensive, such as housekeeping improvements and direct recycle of material without reprocessing. Eventually, more expensive and complex projects begin to emerge for equipment redesign and process modification. Product reformulation is often one of the last waste minimization techniques to find application. Product reformulation must overcome many obstacles and its successful use is usually considered a mark of a mature waste minimization program.

The waste minimization program at 3M is over 11 years old and is definitely in the mature stage. New and advanced waste minimization techniques are beginning to emerge. Some examples follow:

1. Products are being reformulated so that they themselves will not be classified as RCRA hazardous waste when disposed by the customer. For example, cadmium has been eliminated from an entire product line, mercury from another, and asbestos from still another. New products being developed are screened to identify those that may pose a future disposal problem and alternative formulations are being investigated.

2. A new computer system in the corporate purchasing department lists surplus materials at plant locations. Before any new materials are purchased for a plant, the purchasing department checks to determine if they may be available at some other plant. Before this system was implemented, some surplus materials were being disposed as waste.

3. A 3M product used to be made in continuous wide sheets, coated, then cut into required shapes before packaging and sale. The manufacturing process was studied in detail with elimination of waste in mind. The entire process line is now being replaced with new, redesigned equipment and the order of process steps has been changed. The material will still be made in continuous wide sheets but it will be cut into the required shapes before coating. This reduces the amount of coating solution that must be used and allows recycling of the uncoated trimmings directly back into the manufacturing process. In addition, the coating material was reformulated from a solvent base into a water base eliminating the generation of RCRA hazardous waste. It is estimated that this project will eliminate the generation of 475 tons of waste per year and will produce annual savings of approximately $2380000. The capital cost will be $5800000.

Conclusions

By applying the concept of controlling the life cycle of wastes, 3M has documented 129 projects of hazardous waste minimization over the past 12 years. First year reduction of hazardous waste generation attributable to the documented projects (excluding incineration) amounts to 18400 tons per year. It is certain that many more projects have been carried out but were never documented and reported to corporate headquarters.

It is important to note that several of the documented projects involved source reduction of various types. Such practices can greatly reduce the risk of site contamination by eliminating or reducing the amount of waste that must be managed on site.