Waste Reduction Techniques: An Overview

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Increasingly, companies are focusing on waste reduction in the entire manufacturing process rather than just on end-of-the-pipe waste. The techniques used in waste reduction can be broken down into four major categories: managing inventory, modifying production processes, reducing waste volume, and recovering waste. Within each category, examples are given of process or materials changes or modifications that can be implemented to minimize waste.

Liquid, solid, and/or gaseous waste materials are always generated during the manufacture of any product. In addition to creating environmental problems, these wastes represent losses of valuable materials and energy from the production process and require a significant investment in pollution control. Traditionally, pollution control relies on “end-of-the-pipe” and “out-the-back-door” treatments, which require manpower, energy, materials, and capital expenditures. Such an approach removes pollutants from one source - through wastewater treatment or air pollution abatement - but places them somewhere else, such as in a landfill.

More regulations, higher disposal expenses, and increased liability costs have caused industrial and governmental leaders to begin critical examination of end-of-the-pipe control measures. The value of reducing waste during the manufacturing process and, thus, eliminating some pollutants as an end product has become apparent to a number of industries. These companies are looking at broader environmental management objectives rather than concentrating solely on pollution control. As will be documented throughout this article, waste reduction is not only very often economically beneficial for an industry, it also improves the quality of the environment.

Waste reduction techniques should be key components of any cost-effective, comprehensive waste management program. They do not have to be based on complex technology or require large capital expenditures. In fact, waste reduction techniques can be applied to any manufacturing process, from one as simple as making a paper clip to one as complex as assembling the space shuttle. Available techniques range from easy operational changes to state-of-the-art recovery equipment. The common factor in these techniques is that they reduce bottom-line operational costs.

Waste reduction techniques can be broken down into four major categories: managing inventory, modifying production processes, reducing waste volume, and recovering waste. Because the classifications are broad, there will be some overlap. In actual application, waste reduction techniques generally are used in combination in order to achieve the maximum effect at the lowest cost.
Managing Inventory

Proper control over raw materials, intermediate products, final products, and the waste streams associated with production is an important waste reduction technique. In many cases, waste is just raw materials that are out of date, “off-spec,” contaminated, or unnecessary; spill clean-up residues; or final products that are damaged. The cost of disposing of these materials includes not only the actual disposal costs also the cost of the lost raw materials or product. Methods for controlling inventory range from simply changing the ordering procedures to implementing just-in-time manufacturing techniques. Many companies can help reduce waste generation by tightening up and expanding their current inventory control programs. This increased control will significantly affect the three major sources of waste resulting from improper inventory control: excess, out-of-date, and no-longer-used raw materials.

The purchase of only the amount of raw materials needed for a production run or a set period of time is one of the keys to proper inventory control. Often, manufacturers must dispose of excess raw materials simply because they are out of date. Better application of existing inventory management procedures coupled with education of purchasing personnel on the problems and costs of disposing of excess materials can reduce this problem. Also, staff environmental engineers or chemists should evaluate the set expiration dates of raw materials, especially stable compounds, to see if those dates are too short.

The development of review and approval procedures for all raw materials-purchased is another step in establishing an inventory control program. The approval process means that all production materials are evaluated to determine if they contain hazardous constituents and, if so, the alternative nonhazardous substitutes that are available. These review procedures can be developed by one person with the necessary background in chemistry or by a committee comprised of people with a variety of backgrounds.

Often, the information needed for review is on the Materials Safety Data Sheets (MSDS) provided by the chemical supplier. Two companies that have established successful material review programs are IBM and Hewlett Packard.

The ultimate in inventory control procedures is just-in-time (JIT) manufacturing’ in which raw materials go from the receiving dock to the manufacturing area for immediate use and the finished product is shipped out without any intermediate storage. The result is no
For any business, the first step in instituting improved, waste-minimizing operations is to examine the current production process for ways to improve its efficiency.

inventory of either raw materials or completed products. JIT techniques are complex to implement and cannot be used by all facilities, but they can reduce waste significantly. Using JIT techniques, the 3M Company reduced waste generation by 25 percent to 65 percent in its individual plants.³

Modifying Production Processes

Improving the efficiency of a production process can significantly reduce waste generation at the source. In fact, some of the most cost-effective waste reduction techniques are simple and relatively inexpensive changes in production procedures. Available techniques include (1) improving current operation and maintenance procedures, (2) changing the materials used in production, and (3) modifying existing equipment or purchasing more efficient - and more cost-effective - equipment.

Improving operation procedures

Improved operation procedures are quite simply methods that make optimum use of the raw materials used in the production process. Such methods are neither new or unknown, are usually inexpensive to institute, and involve little or no capital expenditure. For example, one producer of breaded foods instituted a number of the operational changes such as dry cleanup, installation or modification of drip trays under processing equipment, and better systems for collecting and handling of waste material. These relatively modest changes resulted in the following:

- Decreased water usage for cleanup by about 30 percent,
- Eliminated the landfilling of waste solids,
- Reduced the organic load of the wastewater by almost 80 percent, and
- Increased revenues as the company sold 2,359,000 kilograms (5.2 million pounds) a year of solids to recovery firms.⁴

For any business, the first step in instituting improved, waste-minimizing operations is to examine the current production process for ways to improve its efficiency. A review would include all segments of the process from the delivery of raw materials through production to final product storage. Table 1 lists some examples of operational changes that can reduce waste generation and that should be considered in a review.
One important area commonly overlooked or not given proper attention in many manufacturing facilities is material handling. Proper material handling ensures that raw materials reach the production area without loss from spills, leaks, or contamination. Proper procedures also ensure that materials are efficiently handled in the production process.

Another critical area is maintenance. One company found that one fourth to one half of its excess waste load resulted from poor maintenance. A strict maintenance program that stresses corrective and preventive maintenance can reduce waste generation caused by equipment failure. Such a program will help spot potential sources of ‘release and correct the problem before any material is lost. A good maintenance program is important because the benefits of the best waste reduction program can be wiped out by just one leak or equipment malfunction.

A maintenance program can include maintenance cost tracking and preventive maintenance scheduling and monitoring. To be effective, a maintenance program should be developed and followed for each operational step in the production process, with special attention given to potential problem points. A strict schedule and accurate records on all maintenance activities should be maintained. Computerized maintenance scheduling and tracking programs are available from a variety of vendors. A comprehensive program should
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Table 1. Examples of Operational Changes To Reduce Waste

<table>
<thead>
<tr>
<th>Operational Change</th>
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<tbody>
<tr>
<td>Reduce raw material, and product loss caused by leaks, spills, drag-out, and off-spec process solution.</td>
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<tr>
<td>Schedule production to reduce equipment cleaning: paint manufacturers can make light paint before dark paint so that the vats do not have to be cleaned out between batches.</td>
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<tr>
<td>Inspect component parts before they are processed to reduce number of rejects.</td>
</tr>
<tr>
<td>Consolidate types of equipment or chemicals to reduce quantity and variety of waste.</td>
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<tr>
<td>Improve cleaning procedures to reduce generation of dilute waste: use dry clean-up techniques, use mechanical wall wipers or squeegees, use pigs or compressed gas to clean pipes, increase the time that parts drain.</td>
</tr>
<tr>
<td>Segregate waste products to increase recoverability.</td>
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<tr>
<td>Optimize operational parameters such as temperature, pressure, reaction time, concentration, and chemicals to reduce by-product or waste generation.</td>
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<tr>
<td>Develop employee training procedures on waste reduction.</td>
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<tr>
<td>Evaluate need for each operational step and eliminate those that are unnecessary.</td>
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<tr>
<td>Collect spilled or leaded material for reuse.</td>
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</table>

also include predictive maintenance. This approach provides the means to schedule future repairs or replacement of equipment relative to its current condition. A number of nondestructive testing technologies are available for making these evaluations.6

Once proper operating and maintenance procedures are established, they must be fully documented and made part of the employee training program. In fact, a comprehensive training program is a key element of any effective waste reduction program. Industry case studies show that, through training, a dairy plant,7 a semiconductor manufacturer,8 and a furniture plant9 reduced waste by 14 percent, 40 percent, and 10 percent, respectively.

For a program to be effective, all levels of personnel from the line operator to the corporate executive officer should be included. The
goal of any program is to make every employee aware of waste generation, its impact on the company and the environment, and ways it can be reduced. Written materials should be prepared and used in conjunction with hands-on training. The training should be an on-going process with review updates and interaction between employees and supervisors on a regular basis.

**Changing to less hazardous materials**

Hazardous materials used in either a product formulation or a production process may be replaced with a less hazardous or nonhazardous material. Reformulating a product to contain less hazardous material will reduce both the amount of hazardous waste generated during the product’s formulation and in its end use. A less hazardous material used in a production process will generally reduce the amount of hazardous waste produced and, in turn, reduce the cost of capital equipment needed to meet environmental regulatory limits. Some examples of changing materials to reduce waste generation are given in Table 2.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Material Change</th>
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<tbody>
<tr>
<td>Household appliances</td>
<td>Eliminated cleaning step by selecting lubricant compatible with next process step.</td>
</tr>
<tr>
<td>Textile</td>
<td>Reduced phosphorus in wastewater by reducing use of chemicals containing phosphates.</td>
</tr>
<tr>
<td>Aerospace</td>
<td>Replaced cyanide cadmium plating bath with a noncyanide bath.</td>
</tr>
<tr>
<td>Ink manufacture</td>
<td>Removed cadmium from product.</td>
</tr>
<tr>
<td>Textile</td>
<td>Used ultraviolet light instead of biocides in cooling towers.</td>
</tr>
</tbody>
</table>
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Although product reformulation is one of the more difficult waste reduction techniques, it can be very effective. Examples of product reformulation include eliminating pigments containing heavy metals from ink, dyes, and paint formulations; replacing phenolic biocides with other less toxic compounds in metalworking fluids; and developing new paint, ink, and adhesive formulations based on water rather than on organic solvents.

Hazardous chemicals used in the production process can also be replaced with less hazardous or nonhazardous materials. Changes can range from switching to purer raw materials to replacing solvents with water-based products. The latter is a widely used waste reduction technique and is applicable to many industries. For example, a diesel engine remanufacturing facility that switched from cleaning solvents and oil-based metalworking fluids to water-based products reduced its coolant and cleaning costs by about 40 percent. Also, the company was able to eliminate one cleaning step, and it found that since machine filters lasted twice as long, material and labor costs were reduced.

A word of warning: one important area that is sometimes overlooked in material changes is the impact on the total waste stream. Switching from a solvent-based to a water-based product can increase wastewater volumes and concentrations. These increases could adversely affect the current wastewater treatment system, cause effluent limits to be exceeded, and possibly increase wastewater treatment sludge production. Thus, before any change is made, its impact on all discharges must be evaluated.

Modifying or changing equipment

Waste generation may be reduced by installing more efficient equipment or by modifying existing equipment to take advantage of better production techniques. Not only can new or updated equipment process materials more efficiently, it produces less waste. Also, by reducing the number of rejected or off-specification products, high efficiency systems reduce the amount of material that must be reworked or discarded. Some examples of equipment and process modifications are listed in Table 3.

Modification of existing equipment can be a highly cost-effective method to reduce waste generation. In many cases, relatively simple and inexpensive modifications can help ensure that materials are not wasted or lost. Such modifications can be as easy as redesigning parts racks to reduce dragout in electroplating operations, installing better seals on process equipment to eliminate leakage, or installing drip pans under equipment to collect leaking process material for reuse. One
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chemical company reduced the waste from a sump in a production area from 31,750 kilograms a year to 1,360 kilograms a year by installing a sight glass, using better pump seals, and purchasing a broom for dry clean-up.11

Installing new, more efficient equipment and, in some cases, modifying current equipment will require capital investment in equipment, facility modifications, and employee training. The extent of the investment will vary greatly with the type of equipment used. These investments, however, can have a rapid payback. For example, a power tool manufacturer replaced a spray solvent paint system with a water-based electrostatic immersion painting unit. This new equipment paid for itself in just over one year by reducing raw material costs by $600,000 a year and waste disposal costs by 97 percent and greatly increasing productivity.12

Reducing Waste Volume

Volume reduction includes techniques to separate toxic, hazardous, and/or recoverable wastes from the total waste stream. These techniques are usually used to increase material recoverability; reduce waste volume and, thus, disposal costs; or increase management options. Table 4 lists some examples of volume reduction techniques that have been used successfully in industry. The available techniques range from simple segregation of wastes at the source to complex concentration technology.
## Table 3. Examples of Waste Reduction Through Equipment or Process Modifications

<table>
<thead>
<tr>
<th>Process</th>
<th>Equipment or Process Modification</th>
</tr>
</thead>
</table>
| Parts cleaning           | - Enclose all solvent cleaning units  
- Use refrigerated freeboard on vapor degreaser units  
- Improve parts draining before and after cleaning  
- Use mechanical cleaning devices  
- Use plastic bead blasting |
| Surface finishing        | - Prolong process bath life by removing contaminants  
- Redesign part racks to reduce drag-out  
- Reuse rinse water  
- Install spray or fog nozzle *rinse systems*  
- Properly design and operate all rinse tanks  
- Install drag-out recovery tanks  
- Install rinse water flow-control valves  
- Install drip racks and drain boards |
| Surface coating          | - Use airless air-assisted spray guns  
- Use electrostatic spray-coating system  
- Control coating viscosity with heat units  
- Use high solids coatings  
- Use powder coating systems |
| Equipment cleaning       | - Use high-pressure rinse system  
- Use mechanical wipers  
- Use counter-current rinse sequence  
- Reuse spent rinse water  
- Use “pigs” to clean lines  
- Use compressed gas to blow out lines |
| Preventing spills/leaks  | - Use bellow-sealed valves  
- Install spill basins or dikes  
- Use seal-less pumps  
- Maximize use of welded pipe joints  
- Install splash guards and drip boards  
- Install overflow control devices |
Table 4. Examples of Waste Reduction Through Volume Reduction

<table>
<thead>
<tr>
<th>Industry</th>
<th>Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-Ray Film</td>
<td>Segregates polyester film’s scrap from other production waste and recycles.</td>
</tr>
<tr>
<td>Printed Circuit Boards</td>
<td>Uses filter press to dewater sludge to 60-percent solids and sends sludge to metal recovery.</td>
</tr>
<tr>
<td>Pesticide Formulation</td>
<td>Uses separate baghouses on each process line to collect and recycle dust into product.</td>
</tr>
<tr>
<td>Paint Formulation</td>
<td>Segregates and reuses tank cleaning solvents in paint formulations.</td>
</tr>
<tr>
<td>Furniture</td>
<td>Segregates and reuses solvents used-to flush spray coating lines and pumps as coating thinner</td>
</tr>
</tbody>
</table>

Segregating waste at the source

Segregation of wastes, is, in many cases, a simple and economical technique for waste reduction. For example, by segregating wastes at the source of generation and handling the hazardous and nonhazardous wastes separately, the volume of waste and, thus, the cost of managing it are reduced. Also, the uncontaminated or undiluted wastes may be reusable in the production process or sent off-site for recovery.

This technique is applicable to a wide variety of waste streams and industries and usually involves simple changes in operational procedures. For example, in metal finishing facilities, wastes containing different types of metals can be treated separately so that the metal values in the sludge can be recovered. Spent solvents or waste oils that are kept segregated from other solid or liquid waste may be recyclable. If wastewater containing toxic material is kept separate from uncontaminated process water, the volume of water that must be treated is reduced.

A commonly used waste segregation technique is to collect and store washwater or solvents used to clean equipment (such as tanks, pipes, pumps, or printing presses) for reuse in the production process.
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This technique is used by paint, ink, and chemical formulators as well as by printers and metal fabricators. For example, a printing firm segregates and collects toluene used for press and roller clean-up operations. By segregating the used toluene by color and type of ink contaminant, the company can reuse it later for thinning the same type and color of ink. Recovery of 100 percent of the waste toluene has totally eliminated a hazardous wastestream.

Concentrating waste

Various techniques are available to reduce the volume of a waste through physical treatment. Such techniques usually remove a component of the waste such as water. Available concentration methods include gravity and vacuum filtration, evaporation, ultrafiltration, reverse osmosis, freeze vaporization, filter press, heat drying, and compaction. Many of these methods are actually recovery techniques and will be discussed further in the next section.

Unless the material can be recycled, to concentrate a waste so that more of it can be “fit into a drum” is not waste reduction. In some cases, concentration of a waste stream may also increase the likelihood that the material can be reused or recycled.

Recovering Waste

Recovering waste is a highly cost-effective waste management alternative. Waste recovery techniques can help eliminate waste disposal costs, reduce raw material costs, and possibly provide income from a salable waste. Table 5 gives examples of various waste recovery techniques being used in industry.
Table 5. Examples of Waste Reduction Through Recovery and Reuse

<table>
<thead>
<tr>
<th>Industry</th>
<th>Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mirror manufacturer</td>
<td>Recovers spent xylene using a batch-distillation system.</td>
</tr>
<tr>
<td>Printed circuit boards</td>
<td>Uses an electrolytic recovery system to recover copper and tin/lead from process wastewater.</td>
</tr>
<tr>
<td>Power tools</td>
<td>Recovers alkaline degreasing baths using an ultra-filtration system.</td>
</tr>
<tr>
<td>Hosiery</td>
<td>Reconstitutes and reuses spent dye baths.</td>
</tr>
<tr>
<td>Pickles</td>
<td>Transfers waste brine pickle solution to a textile plant as a replacement for virgin acetic acid.</td>
</tr>
<tr>
<td>Chemical manufacturer</td>
<td>Uses spent electrolyte from one division as raw material by another.</td>
</tr>
</tbody>
</table>

The effective use of recovery depends on the segregation of the recoverable waste from other process wastes or extraneous material. This segregation ensures that the waste is uncontaminated and that the concentration of recoverable material is maximized. Some companies have assigned the responsibility for the handling, collection, and scheduling for recovery of waste material to one individual to ensure that the maximum value of the waste can be recovered.

Waste recovery can take place either on-site or at an off-site facility.

**On-site recovery**

In most cases, the best place to recover process wastes is at the production facility. Waste can most efficiently be recovered at the point of generation when the possibility of contamination by other waste material is reduced, as in the risk involved with handling and
The upgrade of a waste into a product requires a strong commitment from the generator to find markets, both inside and outside the company, for the waste material.

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transporting waste materials. Wastes that are simply contaminated versions of the raw materials used in the manufacturing process are good candidates for in-plant recycling.

Some waste streams can be recycled directly back into the original production process as raw material. This redirection is usually accomplished when the waste material is lightly contaminated or is excess raw material. Examples include cleaning waste from printers, coaters, and chemical or product formulators; electroplating drag-out solutions; process solutions from filter changes; and dust collector residue from pesticide formulators. Lightly contaminated waste can sometimes be reused in operations that do not require materials of the higher quality. For example, spent high-purity solvents generated during the production of microelectronics can be reused in less critical metal degreasing operations, or a caustic waste material can be reused to treat an acid waste stream.

Some waste may have to undergo some type of purification before it can be reused. A number of physical and chemical techniques available on the market can be used to reclaim a waste material. These techniques range from simple filtration to state-of-the-art techniques such as freeze crystallization. The method of choice will depend on the physical and chemical characteristics of the waste stream, the economics of recovery, and the operational requirements. Most on-site recovery systems will generate some type of residue (contaminants removed from the recovered material). This residue can either be processed for further recovery or properly disposed. Economic evaluations of any recovery technique must include the management of these residues.

Off-site recovery

Wastes may not be recovered at an off-site facility when the equipment is not available to recover on-site, not enough waste is generated to make an in-plant system cost effective, or when the recovered material cannot be reused in the production process. Off-site recovery usually entails recovering a valuable portion of the waste through chemical or physical processes. Some materials that are commonly reprocessed off-site are oils, solvents, electroplating sludges and process baths, lead-acid batteries, scrap metal, food processing waste, plastic scrap, and cardboard. The cost of off-site recycling will depend on the purity of the waste and the market for the waste or recovered material.

In some situations, a waste may be transferred to another company for use as a raw material in its manufacturing process. This exchange can be economically advantageous to both firms as it will
reduce the waste disposal costs of the generator and reduce the raw material costs of the user. For example, an X-ray film manufacturer found that it could produce a salable product from waste film stock. The company installed equipment that flakes and bales waste polyester-coated film stock, which is then sold as raw material input to another firm. The more than 9 million kilograms (20 million pounds) of film stock exchanged each year represent $200,000 annual savings in collection, transport, and processing costs and an annual profit of $150,000 from the sale of the materials.\textsuperscript{16}

The upgrade of a waste into a product requires a strong commitment from the generator to find markets, both inside and outside the company, for the waste material. In some cases, the production process or the waste may have to undergo some modification to make a more salable product. Regional waste exchanges have been set up by a number of states to help companies find markets; these exchanges act as information clearinghouses of wastes available and wanted. The service usually offered is a listing of wastes available from generators and wanted by users in a catalog or computer database form.

\section*{Getting Help}

A wide range of waste reduction techniques currently exist and are available for most manufacturing processes. However, technology alone will not reduce waste generation. Only a comprehensive waste reduction program will be successful. Such a program should include management commitment, data collection, selection and implementation of cost-effective technologies, employee training and involvement, and program monitoring. The foundation of any successful program is determining what wastes are generated and why they are produced. With this information, a company can identify a range of reduction techniques, evaluate them, and implement the most cost-effective options.\textsuperscript{17}

Specific information on waste reduction techniques is available from a number of sources. The best source, however, is the employees who are actually doing the job. In most cases, they can identify operations and equipment problems that generate waste. Additional information may be obtained from trade associations, trade journals, government research reports, regulatory agencies, and technical assistance groups.

Industrial trade associations can provide the most detailed and current technical information. Many associations have staff experts with extensive knowledge and experience in waste management.\textsuperscript{18} Trade publications are another excellent source of information. Many journals
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contain articles on case studies, current research, vendor information, and suggestions from industrial experts.

Another source of technical information is federal and state regulatory agencies or technical assistance programs. The U.S. Environmental Protection Agency (EPA) has established an Office of Pollution Prevention to help promote waste reduction efforts by the regulated community. Its efforts include research; education, and technical information. The Office has created a Pollution Prevention Information Clearinghouse with an electronic information network that contains information on EPA and state activities, relevant publications, and case studies. Contact the Clearinghouse at (703) 821-4800 for more information.

A number of states have established waste reduction technical assistance programs. The level of assistance offered by these programs varies and may include on-site technical assistance, access to information data bases and documents, workshops, referral services, and research and matching grant programs. Current programs and contacts are listed in the Pollution Prevention Clearinghouse. Check with your respective state environmental agencies to find out if such a program is available in your locality.

Some Final Thoughts

In the final analysis, waste reduction depends on looking at waste in a different way: not as something that inevitably must be treated and disposed of but as what it really is -- a loss of valuable process materials, the reduction of which can have significant economic benefits. On corporate executive summed it up when he said that waste is a specialty product for which a market has not yet been found.
Notes

7. Case study files from the Pollution Prevention Program, North Carolina Department of Natural Resources and Community Development, Raleigh, N.C.
13. Huisinhg, op. cit.
17. Detailed discussions on developing a waste reduction program are covered in the following: H. Freeman, Hazardous Waste Minimization (McGraw-Hill, NY, 1990); U.S. Environmental Protection Agency, Waste Minimization Opportunity Assessment Manual (EPA 625/7-88/003, Hazardous Waste Engineering Research Laboratories, Cincinnati,

North Carolina
Office of Waste Reduction

The Office of Waste Reduction is the lead agency for the state of North Carolina’s pollution prevention efforts. This effort addresses air and water quality, solid and hazardous wastes, and toxic chemicals. The goals are accomplished by providing a wide range of non-regulatory technical assistance, training, policy support, and fiscal support to industries, local governments, and state agencies.

Services Available from the Office of Waste Reduction:

- Information Clearinghouse
- Technical Assistance and On-site Waste Reduction Assistance
- Outreach, Education, and Training
- State Agency Support
- Grants

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