GUIDELINES FOR INDUSTRIAL SOLID WASTE MINIMIZATION

by

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ABSTRACT

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Population and technology are growing fast, and the EPA regulations in reference to solid waste are becoming more restrictive, leading to less landfill space. Therefore, there is a cry for an efficient, feasible solution to this problem. The answer to this cry is solid waste minimization. The Ohio legislature passed a bill that created solid waste management districts. The Mahoning County Solid Waste Management District took charge of the solid waste issues in the metropolitan area of Youngstown, and started studies on the amount of industrial waste generated within its boundary. As a follow-up, the district funded and contracted YSU-Technology Development Corporation to take charge of an industrial waste minimization program that would enlighten and encourage companies to minimize their waste.

This thesis addresses this topic, and attempts to present a guide to waste minimization and recycling. After a brief introduction and background information on the solid waste district and industrial waste generation, minimization approaches and examples for specific industries were discussed. Then YSU-TDC waste audits for selected industries were reviewed and areas where additional information is needed were identified. Finally, a decision maker's guide to waste minimization was presented for each industry. An attempt was made to investigate all the feasible solutions to waste minimization, however, the investigation should not be considered conclusive due to limitations in the information available.

DEDICATION

To my wonderful parents and my loving sister overseas, who sacrificed a great deal financially and emotionally through separation from their only son/brother.

To "Mom" and my true friends that supported me and gave me the interest to take on this challenging task, I dedicate this work.

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CHAPTER I
INTRODUCTION

The increase in the population, combined with changes in lifestyle and technology in the US, has created a need to control the amount of municipal solid waste (**MSW**) being generated. MSW incorporates the heterogeneous mass of refuse from the urban community as well as the more homogeneous accumulation of industrial, mineral, and agricultural wastes. *Scientific American* estimates the amount of waste generated by the increase in population to be 400 billion tons per year (**TPY**). To put that in perspective, this amount could bury the city of Los Angeles 100 meters deep in garbage (3). This problem can be directly traced to the modern technological advances in packaging, mainly the increased usage of plastics. One of the best ways to manage MSW is waste minimization (**WM**). WM limits the consumption of raw materials, and increases the rate of reuse & recovery of waste materials.

Initially, attention was given to how to deal with MSW after it was generated. This attention changed disposal sites gradually from open dumps that generated pollutants that contaminated the air and ground water table, to sanitary landfills. The image of dumps with piles of garbage, seagulls, rodent and insects, caused the *"Not in my backyard"* (**NIMBY**) syndrome, which has created a major obstacle in opening new sanitary landfills. As a result of all these factors combined, sanitary landfill space began to dwindle, and a call for a long term strategy to handle this problem emerged. Solid waste management (**SWM**) was the answer to this call. SWM is the discipline associated with the control of generation, storage, collection, transfer, transportation, processing, and disposal of MSW in a manner that is in compliance with the best principles of economics, engineering, public health conservation, aesthetics, other environmental considerations, and that is also responsive to public attitudes. When all these factors are evaluated and interfaced, and combinations have been matched by value engineering, then the community has developed an integrated solid waste management (ISWM) plan. ISWM is the selection and application of proper technologies, techniques, and management programs to achieve specific waste management objectives and goals. The ISWM hierarchy adopted by US Environmental Protection Agency (USEPA) consist of: Source Reduction, Recycling, Waste Combustion, and Sanitary Landfills as the last option. Although this hierarchy is listed from the most favorable option to the least, the elements are interrelated and complement each other. It is worthy to mention that USEPA does not distinguish between waste combustion and sanitary landfills. Nevertheless, some states' interpretation of the ISWM hierarchy is more stringent. For example, recycling can only be considered after the maximum source reduction is achieved, and waste combustion can only be considered after the maximum recycling is achieved (2). Source reduction measures include, but are not limited to, procedure modification, feedstock substitution and purity improvements, housekeeping and management practices, and increase in the efficiency of machinery and recycling within a waste generation process (3).

A number of federal laws have had an impact on SWM and disposal. In 1899, the River and Harbor Act regulated the dumping of debris in navigable waters and nearby lands. In 1965, the US Congress enacted the Solid Waste Disposal Act (SWDA) which provided ways and means to implement SWM, followed by the National Environmental

Policy Act (**NEPA**) which called for an *Environmental Impact Statement* on every federal project. SWDA was amended by the Resources Recovery Act (**RRA**) of 1970 which shifted the focus of the national SWM from disposal as its primary objective to reuse of recoverable materials and recycling. Progress under the RRA prompted the passage of the Resource Conservation and Recovery Act (**RCRA**) in 1976 which gave the legal basis for implementation of guidelines and standards for SWM. In 1984 the US Congress mandated the Hazardous and Solid Waste Amendments to RCRA (2). The combination of this mandate and other RCRA provisions led to an increase in the cost of construction, maintenance, and management of sanitary landfills. Today's landfills require a geomembrane liner (costly rubber-plastic material), elaborate drainage systems, and monitoring wells during and after the life of sanitary landfills. In addition, industrial waste disposal practices were strongly influenced by the desire to reduce liability under the provisions of the Comprehensive Environmental Response, Compensation, and Liabilities Act of 1980 (**CERCLA**) which provided funding and direct response to uncontrolled (active or closed) hazardous waste landfills.

In order to comply with these laws and regulations, the manager of a solid waste system must conduct systemwide studies to improve the reasoning and implementation rational that allows for the integration of all SWM activities, from source reduction through recycling and finally sanitary landfills. With these changes, attention has shifted to the new strategy of waste diversion to handle MSW. Waste diversion occurs when waste that normally would be delivered to the sanitary landfills is removed from the waste stream and does not use up sanitary landfill capacity. The ability to pay for waste diversion will be decided at public hearings when rates are set for MSW services. Because both the laws and rate-setting hearings require precise reporting of facts about SWM systems, it is important to have an ample data base on waste generation and SWM in the community. Data on source reduction are the most important factor in building the data base, because it must be satisfied first in response to legislation. However, the cost to obtain this data is the greatest, because it is often proprietary information of the source generator. Therefore, fully independent studies must be done, because the data are not reported routinely in the SWM system. So, the cost of such studies may not be justified, since the contribution of source reduction quantities to the waste diversion goal is the smallest of all methods in the hierarchy. The expected waste quantity diverted by commercial reduction is 4% but the expense typically amounts to 20% of the total cost of the data base. By comparison, commercial recycling is expected to yield a 13% waste diversion at a cost of 9% of the total data base (2).

Metcalf & Eddy conducted a study for Ohio Environmental Protection Agency **(OEPA)** in 1990. They found that businesses, due to lack of information, do not recycle and believe that the quantities of recyclable materials they generate are insufficient to make recycling worthwhile (3). As recently as May 22, 1995, president Clinton signed the Paper Reduction Act **(PRA)**. This act encourages the federal government to utilize electronic mail and other mean of communication instead of paper memos.

Keep America Beautiful Incorporated, in cooperation with USEPA, has embarked on a collective project to raise awareness of the necessity to buy goods made from recycled materials, thereby stimulating markets for recyclable. They started a two-year pilot project targeting individuals, local government, institutions, and businesses at fifteen test sites including Northeast Ohio (4).

Mahoning County Solid Waste Management District (**MCSWMD**) surveyed solid waste generation by the 405 industries located in its juristriction during the baseline year of July 1, 1989 through June 1, 1990. Currently, MCSWMD is launching an industrial WM program. Under the program, any one of the 405 industries will be eligible for a free WM audit performed by Youngstown State University Technology Development Corporation (**YSU-TDC**). The WM audit is a systematic procedure for identifying ways to reduce or eliminate waste. The four phases of a WM audit are planing and organization, assessment, feasibility analysis, and implementation. The result of a successful WM program are the conservation of dwindling landfill space and a reduction in operating costs for the industry (5).

The goal of this study was to provide several local industries with a decision-maker's guide to investigating and possibly implementing the WM strategies identified by the YSU-TDC WM audit. This guide will provide the company's environmental manager(s) with a structured approach to investigating the feasibility of implementing each WM strategy.

CHAPTER II
LITERATURE REVIEW

2.1 Background on MCSWMD

In response to RCRA of 1976 and other amendments, the Ohio legislature passed House Bill (HB) 592 on June 24, 1988. The bill issued a mandate for counties to assure all of their residents access to sanitary and safe waste collection, transportation, and deposition. HB 592 required the OEPA Director, with recommendations from the Solid Waste Advisory Council (a division of OEPA under Section 3734.51 of the Ohio Revised Code), to prepare a solid waste management (SWM) plan. The plan was to be adopted by the Director within a year from June 24, 1988. The SWM plan contained mandates for local municipalities to reduce the amount of waste generated in their jurisdictions. In order to comply, the Board of County Commissioners of each county was required to establish a SWM district by March 24, 1989, under the guidelines set forth by Chapter 343 of Ohio Revised Code. As a result, a seven member management policy committee and the Board of Mahoning County Commissioners formed the Mahoning County Solid Waste Management District (MCSWMD) on December 21, 1988 (8).

Complete goals and objectives contained in the district SWM plans must be consistent with the Ohio SWM plan. Each district plan is to contain all 13 points outlined in Revised Code Section 3734.53. These points include: inventories of the source, composition and quantities of solid waste; inventories of solid waste disposal facilities, collection routes, and open dumps; projections of population and solid waste generation changes; a projection of the need for, and strategy for the identification of additional SWM facilities; comparisons of the capital and operating costs of SWM facilities; a schedule for implementation of the plan; a program for providing technical assistance and information regarding Waste Minimization (WM), collection fees, and other projections that the district deems necessary to meet their SWM goals (8) .

A total of seven sanitary landfills are utilized to dispose of solid waste generated within MCSWMD: BFI Carbon Limestone, County Land Development, Mahoning and Central Waste landfills are within MCSWMD. BFI Willowcreek, Kimble and American Landfills are outside the district (8).

The revised Code provides guidelines for establishing fees for solid waste disposal at landfill sites. MCSWMD fees are: $1.50 per ton of waste generated within the district and $3.00 per ton of waste from outside MCSWMD. MCSWMD may enter into a contract with landfills to collect fee surcharges on out-of state waste. However, they can not charge this as part of their fee schedule. As such, BFI Carbon Limestone Landfill collects an additional $1.50 per ton of waste accepted from out of state sources. Since this surcharge is collected with the blessing of MCSWMD, BFI collects recyclable materials as part of the curbside recycling program at no cost to MCSWMD (8).

2.2 Industrial Solid Waste Generation in MCSWMD

A survey was conducted by MCSWMD to determine the amount of MSW and industrial solid waste (**ISW**) generated within its boundary. MCSWMD contains the cities of Campbell, Canfield, Struthers and Youngstown. It also contains the villages of Beloit, Craig Beach, Lowellville, New Middletown, Poland and Sebring. The townships of Austintown, Beaver, Berlin, Boardman, Canfield, Coitsville, Ellsworth, Goshen, Green, Jackson, Milton, Poland, Smith and Springfield, are also within the MCSWMD. The Amended Substitute House Bill 656 of the 117^{th} General Assembly revised districts boundaries as follows: "*If a municipal corporation is located in more than one district, the entire municipality is to be under the jurisdiction of the district in which a majority of its population resides.*" Therefore, a small segment of Youngstown lying within Trumbull County was included in the MCSWMD. The national average MSW generation rate of 3.58 pounds per person per day, as determined by Franklin Associates Incorporated, was multiplied by the population of 264,335 persons and 365 day per year. The total was divided by 2000 to convert pound to tons (OEPA recommended formula). The calculated residential and commercial MSW was 172,703 TPY (5).

MCSWMD conducted a survey between September and December, 1990 to solicit a variety of information regarding ISW generation rates, recycling, composition, WM activities and disposal within its boundaries. The federal government created the Standard Industrial Classification (**SIC**) system for use in classifying establishments by the type of activity in which they are engaged. Only SIC code 20-39 were incorporated in the survey, because they generate the majority of ISW (5).

The *1991 Ohio Harris Industrial Directory* (5) was consulted as the primary source of information in preparing a list of all industries within the MCSWMD. The *Directory of Manufacturers in Youngstown & Mahoning County* (5) was also utilized as a supplementary source. A survey was mailed to 405 industries with SIC codes 20-39. Initially, around 35% responded, and after a second mailing and phone contact, the percentage increased to 56%. The industries responding represent 61% of the total industrial employment in the MCSWMD. The total employment in industrial SIC groups with no responses was limited to 0.79% . The average generation of ISW per employee was used to estimate the total tonnage for these groups. The amount of waste in pounds per employee for each SIC code determined from the survey, was multiplied by the total corresponding SIC employment. This resulted in an estimate of the total ISW quantity for each SIC code. Summing the total for all SIC codes provided an estimate of the total ISW generation for MCSWMD (**Table 2.1**). Industries were also asked to furnish their daily ISW generation for different waste categories. The results are presented in **Table 2.2**. Ferrous metals accounted for 29%, paper 19%, stone/clay/sand 18%, aluminum 11%, and other waste 23%. A graphical representation of waste composition is illustrated in **Figure 2.1** Industry groups with high per employee ISW generation rates are generally the largest employers in the MCSWMD. Accordingly, these are the biggest ISW producers. Employers with SIC codes 33-35 account for 55% of the total employment and 79% of the ISW generation in MCSWMD. MCSWMD found the amount of ISW generation to be 109,303 tons during the baseline year of July 1, 1989 through June 30, 1990 (5).

Table 2.1
Industrial Waste Generation in MCSWMD by SIC Code in the Baseline Year (5)

SIC Code	Number of Companies: Responded	Number of Companies: Total	Number of Employees: Responded	Number of Employees: Total	Reported TPY	Tons per Employee	Total # of Employees	Total TPY
20	11	17	867	957	2,254	2.5993	957	2,488
22	0	2	0	60	0	4.8779	60	293[1]
23	6	11	299	404	322	1.0761	404	435
24	9	19	211	389	701	3.3233	389	1,293
25	7	10	91	308	197	2.1615	308	666
26	2	3	380	490	900	2.3684	490	1,161
27	18	38	189	695	729	3.8585	695	2,682
28	5	8	54	107	62	1.1552	107	124
29	0	2	0	24	0	4.8779	24	117[1]
30	7	16	100	556	436	4.3637	556	2,426
31	0	1	0	28	0	4.8779	28	137[1]
32	13	20	308	494	3,433	11.1456	494	5,506
33	20	30	1,543	1,826	32,159	20.8421	1,826	38,058
34	44	83	1,701	2,950	10,265	6.0347	2,950	17,803
35	47	86	1,772	3,080	17,252	9.7359	3,080	29,987
36	10	16	351	657	1,434	4.0868	657	2,685
37	10	13	514	807	2,034	3.9579	807	3,194
38	6	13	99	182	57	0.5751	182	105
39	11	17	132	193	101	0.7630	193	147
Total	226	405	8,611	14,207	72,337		14,207	109,303

Average Tons Per Employee = 4.8779 Tons/Employee

Primary Product

- Food and kindred products
- Tobacco
- Textile mill products
- Apparel
- Lumber and wood, except furniture
- Furniture and fixtures
- Paper and allied products
- Printing and publishing
- Chemicals and allied products
- Petroleum refining
- Rubber products
- Leather products
- Stone, clay, glass and concrete
- Primary metals
- Fabricated metal products
- Machinery, except electrical
- Electrical machinery
- Transportation equipment
- Scientific equipment
- Miscellaneous manufacturing

[1]Since there was no response, these values were calculated using the average Tons/Employee

Table 2.2
Weigh to Volume Conversion for Solid Waste (5)

Material	Number of Cubic yd/T
Wood	05.00
Aluminum	13.50
Ferrous Metals	11.00
Non-Ferrous Metals	12.00
Fabric	06.60
Paper	03.90
Glass	02.25
Stone/Clay/Sand	00.80
Concrete	00.80
Plastics	28.00
Rubber	00.80
Ash (including Flyash)	00.75
Sludge	01.00
Food	03.30
Non-Hazardous Chemicals	01.25
Composites	05.90
Other	03.00

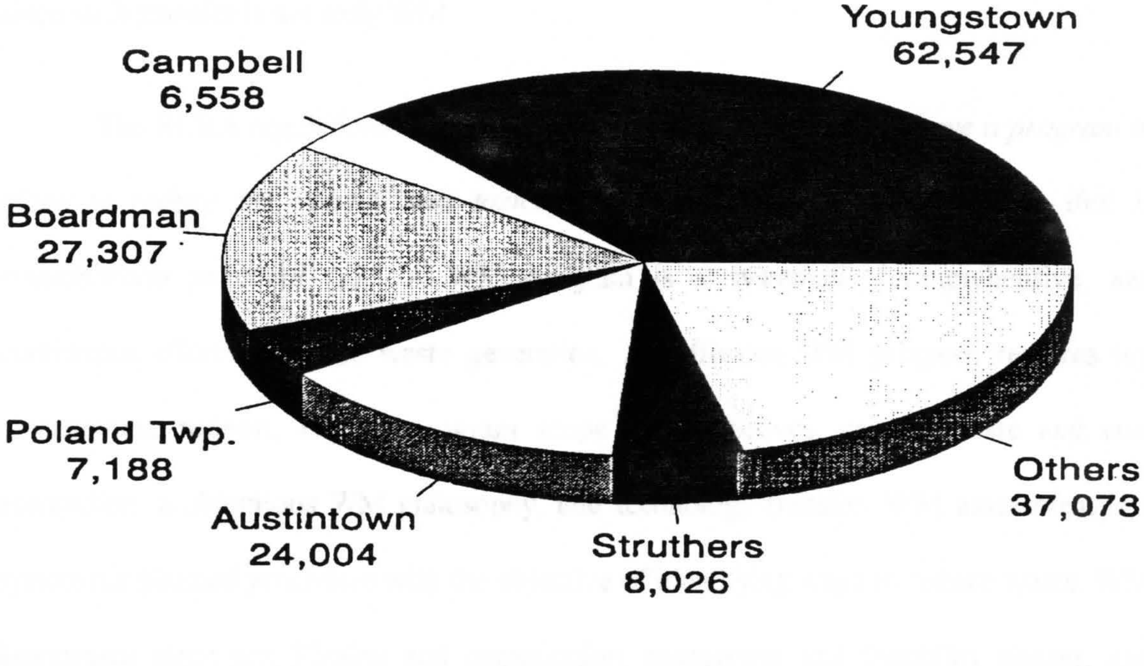

Figure 2.1
Generation Sources & Amounts of MSW for MCSWMD in Tons (1989-1990)

2.3 Approaches to Industrial Solid Waste Minimization

This section concentrates on procedures that provoke people to search, screen, and put into practice measures involving administrative, material, or technology changes that result in WM. It is also a source of concepts and propositions for developing and implementing a WM program. If the company follows the WM approaches it can save money by reducing its disposal cost, meet federal and state WM goals and policy, protect the environment and reduce its potential liabilities, and protect public and worker health and safety. The present focus of WM activities is on hazardous waste. However, most of the concepts and approaches also apply to solid waste. It is important that all pollutant emissions into other media (i.e. air or water) be considered as part of a WM program, since such transfer is not truly WM.

The RCRA regulations require hazardous waste generators to "*have a program in place to reduce the volume and toxicity of waste generated to the extent that is economically practical (1).*" A WM program is a systematic, comprehensive, and continuous effort to reduce waste generation. An effective WM program requires top management support, explicit program scope and objectives, careful waste and cost accounting, a ubiquitous WM philosophy, and technology transfer. WM assessment is a systematic planned procedure with the objective of identifying ways to reduce waste. WM assessment steps are: Planing and organization, assessment and feasibility phases, and implementation (1).

2.3.1 Planing and Organization:

A comprehensive WM program affects many occupational groups within the company; therefore, it needs to bring these groups together to reduce waste. The program structure must be flexible enough to accommodate unexpected changes. The developmental activities of a WM program include:

1. Getting management commitment.
2. Staffing the program task force.
3. Setting WM goals.
4. Overcoming barriers.

The company's management will support a WM program if persuaded that benefits will outweigh costs. This support is communicated to the employees through a formal policy statement or management directive. This policy cannot be successful without the employees engagement. Bonuses, awards, plaques, and other form of recognition are often used to provide motivation, and to boost employee cooperation and participation.

The task force should include members of any department in the company that has a serious interest in the outcome of the program. Small companies should have at least two people involved for perspectives and different viewpoints. **Table 2.3** lists the typical responsibilities of a WM program task force.

Table 2.3

The typical responsibilities of WM program task force (1)

- Secure commitment and a policy statement from upper management.
- Establish overall WM program goals and waste tracking system.
- Prioritize the waste streams or facility areas for assessment.
- Select assessment teams.
- Conduct/supervise assessments, technical or economic feasibility analyses of favorable options.
- Select and justify feasible options for implementation.
- Obtain funding and establish schedule for implementation.
- Monitor/direct implementation progress and performance of the option, once in operation.

The number one priority for the task force should be establishing measurable, quantifiable goals, since qualitative goals can be interpreted ambiguously. These goals should be incorporated into the appropriate individual departmental goals, and should be reviewed periodically to reflect any changes. WM should not be a one-time effort, but an ongoing process that is continually reevaluated. **Table 2.4** list the attributes of effective WM goals.

Although WM projects can reduce production costs and improve environmental conformity, they can lead to conflicts between different groups within the company. **Table 2.5** lists examples of jurisdictional conflicts that can arise during the implementation of a WM project.

Table 2.4
The attributes of effective WM goals (1)

- Acceptable to those who will work to achieve them.
- Flexible and adaptable to changing requirements.
- Motivational, understandable and measurable over time.
- Suitable to the overall corporate goals and mission.
- Achievable with a practical level of effort.

The attitude of "*If it ain't broke, don't fix it*" stems from the desire to avoid the unknown, and the fear that a new WM option may not work. Therefore, management must announce that "It is broke." When a person does not fully understand the nature of the proposed option and its impact on operation, the feeling that "*It just won't work*" comes up. One way of overcoming this feeling is to encourage idea-generating sessions where each option is evaluated on its merit. When unused feed materials are recovered and recycled back to the process, the fear of diminishing product quality comes up. Setting up a pilot study within the facility, or observing the particular option in operation at another facility would take care of this fear (1).

2.3.2 Assessment Phase:

The purpose of the assessment phase is to develop a comprehensive set of WM options and to identify the attractive options that deserve additional, more detailed understanding of the plant's waste and operations. **Table 2.6** lists information that can be useful in conducting the assessment.

Table 2.5
Examples of jurisdictional conflicts that can arise during the implementation of a WM project (1)

PRODUCTION:
- A new operating procedure will reduce waste but may also be a bottleneck that decreases the overall production rate.
- Production will be stopped while the new process equipment is installed.
- A new segment of equipment has not been demonstrated in a similar service. It may not work here.

FACILITIES/MAINTENANCE:
- Adequate space or utilities are not available for the installation and operation of the new equipment.
- Engineering or construction work force will not be available in time to meet the project schedule.
- Substantial maintenance may be required.

QUALITY CONTROL:
- More rework of finished products and intensive QC may be required.

CLIENT RELATIONS/MARKETING:
- Changes in product characteristics may affect client acceptance.

INVENTORY:
- A program to reduce inventory may lead to stockouts during high production demand.

FINANCE:
- Money is not sufficient to fund the project.

PURCHASING:
- Existing binding contracts/stocks will delay the replacement of common material with a substitute.

ENVIRONMENTAL:
- Accepting another plant's waste as a feedstock may require a lengthy resolution of regulatory issues.

WASTE TREATMENT:
- Use of a new raw material will adversely impact the present wastewater treatment facility.

Table 2.6

Information that can be useful in conducting a WM assessment (1)

DESIGN INFORMATION:

- Process flow diagrams.
- Material and heat (design and actual) balance for production and pollution prevention processes.
- Operating manuals and process descriptions.
- Equipment lists, specifications, data sheets, layouts and work flow diagrams.
- Piping and instrument diagrams.
- Plot and elevation plans.

ECONOMIC INFORMATION:

- Waste treatment and disposal cost.
- Product, utility, and raw material cost.
- Operating and maintenance costs.
- Departmental cost accounting reports.

ENVIRONMENTAL INFORMATION:

- Biennial hazardous waste report.
- Emission inventory.
- Environmental audit reports.
- Hazardous waste manifests.
- Permits and/or permit applications.
- Waste analyses.

RAW MATERIAL/PRODUCTION INFORMATION:

- Material safety data sheets and application diagrams.
- Operating procedures, and operator data logs.
- Product composition, batch sheets and raw material inventory records.
- Production schedules.

OTHER INFORMATION:

- Company environmental policy statements.
- Standard procedures.
- Organization charts.

One of the first tasks of WM assessment is to classify and characterize the facility waste streams. Information on waste streams can come from a variety of places depending on the waste type. Hazardous waste manifests do provide information on this type of waste, but do not cover nonhazardous solid waste, air and water pollution. The National Pollutant Discharge Elimination System (NPDES) monitoring reports will include the volume and constituents of wastewater that are released. Also, toxic substance release inventories prepared under the "*right to know*" provisions of the Superfund Amendment and Reauthorization Act (SARA) Title III, Section 313 may provide valuable information on emission into land, water, and air. Billing records for solid waste disposal may provide an initial estimate of quantities generated.

Flow diagrams provide the basic means for identifying and organizing information that is useful for the assessment. Material balances are important for many WM projects, since they allow quantification of losses or emissions that were previously unaccounted for. Also, material balances provide data to assist in developing a baseline for tracking progress of the WM efforts, estimate the size and cost of additional equipment and other modifications, and evaluate economic performance. The mass-balance formula is the simplest way of illustrating this idea: **Mass in = Mass accumulated + Mass out.** The mass-balance should be made <u>individually</u> for all components that enter and exit the process. Material balances can assist in estimating concentrations of waste constituents where analytical test data is limited. They are particularly useful if there are points in the production process where it is unattainable or uneconomical to collect analytical data.

Material balances are easier, more meaningful, and more accurate when they are done for individual units, operations, or processes. This effort will emphasize interrelationships between different operating units or departments. The time span is important when constructing a material balance. Material balances constructed over a shorter time span require more precise and frequent stream monitoring in order to close the balance. Material balances performed over the duration of a complete production run are typically the easiest to construct and are sufficiently accurate. Time duration also affects the use of raw material purchasing records and on site inventories for calculating input material quantities. The quantities of material purchased during a particular time period may not necessarily equal the quantity of materials used in production during the same time period, since purchased materials can accumulate in warehouses or stockyards. EPA's Office of Toxic Substances (**OTS**) has prepared "*Estimating Releases and Waste Treatment Efficiencies for the Toxic Chemicals Inventory Form (1).*" This report (EPA 560/4-88-02) contains additional information applicable to a WM evaluation when the balances are for individual operations being evaluated rather than the entire facility, when the variations in the flow over time is accounted for, and when the data is used from individual streams rather than from the aggregate stream (1).

Measuring waste mass flows and compositions is something that should be done systematically. Changes in waste generation cannot be meaningfully measured unless the information is collected both before and after a WM option is implemented. Ideally, all waste streams and plant operations should be assessed. However, prioritizing the waste streams and/or operations to evaluate is necessary when available funds and/or personnel are limited. The most important waste should come first, followed by wastes of lower priority. **Table 2.7** lists the typical considerations for prioritizing waste streams to assess. Small or large businesses with only a few waste generation operations should assess their entire facility. The execution of good operating practices that involve procedural or organizational measures should be implemented on a facility-wide basis.

Table 2.7
Typical considerations for prioritizing waste streams to assess (1)

- Available budget for the WM assessment project.
- Compliance with current and future regulations.
- Costs of waste treatment and disposal.
- Hazardous properties of the waste and other safety hazards to employees.
- Potential for minimization, removing bottlenecks in output/waste treatment, and recovery of valuable by-products.
- Potential for environmental and safety liability.
- Quality of waste.

The WM program task force is concerned with the whole plant. However, it should include people with direct responsibility and knowledge of the particular waste stream or area of the plant. Production operators and line employees must not be overlooked as a source of WM suggestions, since they possess firsthand knowledge and experience with the process. "Quality circles" are useful since they involve the production people who are closely associated with the operations, and cultivate participation and commitment to improvement. Outside people should be considered in situations such as the assessment and implementation phases (1).

After the selection of a specific area or waste stream, and the assessment team, the assessment continues with a visit to the site. In the case where the entire assessment team is employed at the plant being assessed, the team should have become very familiar with the specific area in the process of collecting the operating and design data. Although the collected information is critical to gaining an understanding of the processes involved, seeing the site is important in order to witness the actual operation. In many instances, a process unit is operated differently from the method originally described in the operating manual. Modifications may have been made to the equipment that were not recorded in the flow diagrams or equipment lists. A site inspection by all team members is helpful after the site information has been collected and reviewed. When the assessment team includes members employed outside of the plant, the team should prepare a list of needed information and an inspection agenda. The agenda and information list are given to the appropriate plant personnel in the areas to be assessed early enough before the visit to allow them to assemble the information in advance. **Table 2.8** provides useful guidelines for the site inspection.

In carrying out the site inspection, the assessment crew should follow the process from the point where raw materials enter the area to the point where the products and the wastes leave the area. It should be recognized that the plant's waste treatment area itself may also offer opportunities to minimize waste. This inspection often results in forming introductory conclusions about the causes of waste generation. Full validation of these conclusions may require additional data collection, analysis, and/or site visits (1).

Table 2.8

Useful guidelines for the site inspection (1)

• Provide staff contacts in the area being assessed with an agenda that covers all points requiring clarification, several days before inspection.
• Schedule the inspection to coincide with the particular operation that is of interest.
• Monitor the operation at different times during the shift, and if necessary, during all shifts, especially when waste generation is highly dependent on human involvement.
• Interview the operators, shift supervisors, and foreman in the assessed area. Do not hesitate to question more than one person if the answer is not forthcoming. Assess the operators' and their supervisors' awareness of the waste generation aspects of the operation. Notice their familiarity with the impacts of their operation on other operations.
• Photographs of the area of interest are valuable in the absence of plant layout. They capture many details that may not be remembered at a later date.
• Observe in-house housekeeping, and check for signs of spills or leaks. Visit the maintenance shop and ask about any problems in keeping the equipment leak-free. Assess the overall cleanliness of the site. Pay attention to odors and fumes.
• Assess the organizational hierarchy, and the level of environmental activities coordination between departments. Also, note the administrative controls, such as cost accounting, material purchasing, and waste collection procedures.

Identifying viable options relies both on the expertise and creativity of the team members. Much of the indispensable knowledge may come from their education and on-the-job experience; however, the use of technical literature, contacts, and other sources is always helpful. **Table 2.9** present sources of background information on WM options. The process for identifying options should follow a hierarchy in which source reduction options are explored first, followed by recycling options. Treatment options should be considered only after acceptable WM techniques have been identified (1).

Table 2.9
Sources of background information on WM options (1)

- Trade associations.
- Plant engineers and operators.
- Published literature.
- State and local environmental agencies.
- Equipment vendors.
- Consultants.

Good operating practices are procedural, administrative, or institutional measures that a company can use to minimize waste. These can have a high return on investment with little cost. Good operating practices include the following:

1. Waste minimization programs.
2. Management and personnel practices.
3. Material handling and inventory practices.
4. Loss prevention.

5. Waste segregation.

6. Cost accounting practices.

7. Production scheduling.

Management and personnel practices include employee training, incentives and bonuses, and other programs that encourage employees to conscientiously strive to reduce waste. Material handling and inventory practices include programs to reduce loss of input materials due to mishandling, expired shelf life of time-sensitive materials, and proper storage conditions. Loss prevention minimizes wastes by avoiding leaks from equipment and spills. Waste segregation practices reduce the volume of hazardous wastes by preventing the mixing of hazardous and nonhazardous wastes. Cost accounting practices include programs to allocate waste treatment and disposal costs directly to the departments or groups that generate waste, rather than charging these costs to general company overhead accounts. The departments of groups that generate the waste become more aware of the effects of their treatment and disposal practices, and have a financial incentive to minimize their waste. By judicious scheduling of batch production runs, the frequency of equipment cleaning and the resulting waste can be reduced. Technology changes can range from minor changes that can be implemented in a matter of days at low cost, to the replacement of processes involving large capital costs. Changes in input materials can be made to avoid the generation of hazardous wastes within the production processes. Product changes are performed by the manufacturer of a product with the aim of reducing waste resulting from a product's use. For example, the use of water-based paints instead of solvent-based paints greatly reduces volatile organic compound emissions to the atmosphere (1).

Recycling involves the return of a waste material either to the originating process as a substitute for an input material, or to another process as an input material. Reclamation is the recovery of valuable material from a solid or hazardous waste. Many WM options will be identified in a successful assessment. The screening procedure serves to eliminate suggested options that appear marginal, impractical, or inferior without a detailed and more costly feasibility study. The informal evaluation is an unstructured procedure by which the assessment team or WM program task force selects the options that appear to be the best. This method is especially useful in small facilities, with small management groups, or in situations where only a few options have been generated. No matter what method is used, the screening procedure should consider the following questions:

1. What is the main benefit gained by implementing this option? What other benefits will occur?
2. How much does it cost? Is the cost effective?
3. Does the necessary technology exist to develop the option? Will the option be easy to implement?
4. Does the option have a good track record? If not, is there convincing evidence that the option will work as required?
5. Does the option have a good chance of success?

The number of options chosen for the feasibility analyses depends on the budget, time, and resources available (1).

2.3.3 Feasibility Analysis:

The technical assessment determines whether an intended WM option will work in a specific application. Process examination for individual materials can be done relatively fast, if the options do not encompass major equipment installation or modifications. For equipment-related options or process changes, visits to see existing installations can be arranged through equipment vendors and industry connections. The operator's observations are especially significant and should be compared with the vendor's claims. Bench-scale or pilot-scale demonstration is often essential. Often it is possible to obtain scale-up data using a rental test unit for bench-scale or pilot-scale experiments. Some vendors will install equipment on a trial basis, with acceptance and payment after a prescribed time, if the user is satisfied. **Table 2.10** present typical technical evaluation criteria.

Table 2.10

Typical technical evaluation criteria for WM Options (1)

- Is the system safe for workers? Is space available?
- Will product quality be maintained? Is supplementary labor required?
- Is the new equipment, materials, or procedures compatible with production, operating procedures, work flow, and production rates?
- Are utilities accessible? Or, must they be installed, thereby raising capital costs?
- How long will production be stopped in order to install the system?
- Is special expertise necessary to operate or maintain the new system?
- Does the vendor provide acceptable service?
- Does the system create other environmental problems?

Prior consultation and review with the affected groups (e.g., production, maintenance, purchasing) is needed to ensure the viability and acceptance of an option. If the option calls for a change in production methods or input materials, the project's effects on the quality of the final product must be determined. If after the technical evaluation, the project appears infeseable or impractical, it should be dropped.

The economic evaluation is carried out using standard measures of profitability, such as payback period, return on investment, and net present value. As in any projects, the cost elements of a WM project can be broken down into capital costs and operating costs. A proper perspective must be maintained between the magnitude of savings that a potential option may offer, and the amount of manpower required to do the technical and economic feasibility analyses. **Table 2.11** presents potential capital costs for a typical large WM project. These costs include not only the fixed capital costs for designing, purchasing, and installing equipment, but also costs for working capital, permitting, training, start-up, and financing charges. Many source reduction techniques have the advantage of not requiring environmental permitting in order to be implemented (1).

In making the economic evaluation, it is convenient to use incremental operating costs in comparing the existing system with the new system that incorporates the waste minimization option. "Incremental operating costs" represent the difference between the estimated operating costs associated with the WM option, and the actual operating costs of the existing system, without the option. **Table 2.12** presents the potential changes in operating costs and savings associated with WM projects.

Reducing or evading present and future operating costs affiliated with waste treatment, storage, and disposal are major elements of the WM project economic assessment. For the purpose of assessing a project to reduce waste quantities, some types of costs are larger and more easily quantified. These include: operating, maintenance, transportation, raw materials, pre-disposal treatment costs and disposal fees. It is recommended that savings in these costs be taken into consideration first, because they have a greater effect on project economics and involve less effort to estimate reliably. The remaining elements are usually secondary in their effect and should be included on an as-needed basis in fine-tuning the analysis (1).

A project's profitability is measured using the estimated net cash flow for each year of the project's life. If the project has no significant capital costs, the project's profitability can be judged by whether an operating cost savings occurs or not. If such a project reduces overall operating costs, it should be implemented when practical. For projects with notable capital costs, a more detailed profitability analysis is necessary. The standard profitability measures are: net present value (**NPV**), internal rate of return (**IRR**), and payback period. The project payback period is the amount of time it takes to regain the initial cash outlay. IRR and NPV are both discounted cash flow techniques for determining profitability. Many companies use these methods for ranking capital projects that are competing for funds. Capital funding for a project may well hinge on the ability of the project to produce positive cash flows beyond the payback period to realize acceptable return on investment. Both IRR and NPV recognize the time value of money by discounting the projected future net cash flows to the present. For investment with a low level of risk, an after-tax IRR of 12 to 15 percent is typically acceptable (1).

Table 2.11

Potential capital costs for a typical large WM project (1)

<u>Direct Capital Costs</u>

Site Development:
- Demolition and alteration work.
- Site clearing and grading.
- Walkways, roads, and fencing.

Process Equipment:
- All equipment listed on flow sheets.
- Spare parts.
- Taxes, freight, insurance, and duties on materials.
- Piping and ducting.
- Insulation and painting.
- Electrical.
- Instrumentation and controls.
- Buildings and structures.

New Utility and Service Facilities, Connections to Existing Utilities and Services
Other Non-Process Equipment Construction/Installation:
- Construction/Installation labor salaries and burden.
- Supervision, accounting, time keeping, purchasing, safety, and expediting.
- Temporary facilities.
- Construction tools and equipment.
- Taxes and insurance.
- Building permits, field tests, licenses.

<u>Indirect Capital Costs</u>
- In-house engineering, procurement, and other home office costs.
- Outside engineering, design, and consulting services.
- Permitting costs.
- Contractor's fees.
- Start-up costs.
- Training costs.
- Contingency.
- Interest accrued during construction.

Table 2.12

Potential changes in operating costs & savings associated with WM projects (1)

Changes in costs associated with quality. Product quality may be affected positively or negatively. This may lead to lower/higher costs for scrap, rework, or quality control functions.
Changes in utilities costs. This includes electricity, steam, process and cooling water, inert gas, plant air, or refrigeration. The cost could fluctuate.
Changes in maintenance and operating labor, benefits, and overhead. This may be reflected in changes in overtime hours or in changes in the number of employees. When direct labor costs change, then the overhead and benefit costs will also change. Supervision costs will be affected in large projects.
Changes in overhead costs. The facility overhead costs may be affected on large projects.
Changes in revenues from increased/decreased production. This will result in change in the company's overall revenues.
Changes in operating and maintenance supplies.
Increased revenues from by-products. This will increase the company's revenues.
Input material cost savings. An option that reduces waste usually decreases the demand for input materials.
Insurance & liability savings. A WM option may be significant enough to reduce a company's insurance payments. Also, it may also lower a company's potential liability associated with workplace safety, and remedial clean-up of treatment, storage and disposal facilities.
Reduced waste management costs This includes reductions in costs for: Offsite treatment, storage, and disposal fees for solid or hazardous wastes. State fees and taxes on hazardous waste generators. Transportation costs, permitting, reporting, and record keeping costs. Onsite treatment, storage, and handling costs.

WM projects may reduce the extent of safety hazards and environmental risks for a company. Although these risks can be identified, it is often difficult to predict whether problems will occur, the nature of the problems, and their resulting extent. One way of accounting for the reduction of these risks is to relieve the financial performance requirements (i.e. liability insurance) of the project. It is important that the financial analysts and the decision makers in the company are aware of the risk reduction and other benefits of WM options. Total company cash flow can hinge on implementation of the environmental projects.

A good final report can be an important tool for getting a project implemented. It is especially valuable in obtaining resource allocation for the project. In presenting the feasibility analysis, it is often useful to evaluate the project under different scenarios. Statistical sensitivity analyses that indicate the effect of key variables on profitability are also useful. The report should include, beside the project's cost and expected performance, how it will be implemented. Some of the important issues that must be addressed are:

1. The required resources and how they will be obtained.
2. Whether the technology is established, with mention of successful application.
3. Estimated construction period, and production downtime.
4. How the performance of the project can be evaluated after it is implemented.

Before drawing a conclusion, it is important to discuss the results with the affected departments and to seek their support. By getting the department representatives involved, the chances of projects being implemented are increased. Reduced liabilities and improved image in the eyes of the employees and the community should be discussed. The qualitative evaluation of intangible costs and benefits to the company should be included in the summary of results (1).

2.3.4 Implementing WM Options:

The proponents of the WM assessment program should be flexible enough to develop alternatives or modifications. A company's capital resources may be prioritized toward enhancing future revenues, rather than toward cutting current costs. If this is the case, then a sound WM project could be deferred until the next fiscal period. It is then up to the project sponsor to ensure that the project is reconsidered at that time.

An evaluation team made up of financial and technical personnel can ensure that a sponsor's enthusiasm is balanced with objectivity. The team should review the project in the context of past experience in this area of operation, how the implementation program fits into the company's overall business strategy, what the market and the competition are doing, and advantages of the proposal in relation to competing requests for capital funding. Even when a project promises a high internal rate of return, some companies will have difficulty raising funds internally for capital investment. In this case, the company generally has two major sources to consider:

1. Private; including bank loan and other conventional sources.
2. Government financing; which could be available in some cases. Therefore, the state's Department of Commerce or the US Small Business Administration should be contacted (1).

WM options that involve material, procedural, or operational changes should be implemented as soon as the potential cost savings have been determined. For projects involving equipment modifications or new equipment, the installation of a WM project is essentially no different from any other capital investment project. The phases of a project include planning, design, procurement, and construction.

Options that do not measure up to their original performance expectations may require re-work or modifications. It is important to get warranties from vendors prior to the installation of the equipment. A document prepared through a follow-up evaluation represents an important source of information for future uses of the option in other facilities. The experience gained in implementing an option at one facility can be used to reduce the problems and costs of implementing options at later facilities (1).

The easiest way to measure the actual WM accomplished is by comparing the quantities of waste generated before to after WM implementation. The difference, divided by the original waste generation rate, represents the percentage reduction in waste quantity. It is important to note that this measurement ignores other factors that have an effect on waste generation. The ratio of waste generation rate to production rate is a convenient way of measuring WM. However, this is not free of problems. One of these problems is the danger of using a ratio of typically small quantities to the production rate. Therefore, a distinction should be made between production-related wastes, maintenance-related waste, and clean-up wastes. When expressed as such a ratio, some waste streams may be inversely proportional to production rate.

In measuring WM, the total quantity of an individual waste stream should be measured, as well as the individual waste components or characteristics. Many companies have reported considerable reduction in the quantities of waste disposed. Often, much of the reduction can be tracked to good housekeeping and steps taken to concentrate a dilute aqueous waste. Although concentration, as such, does not fall within the meaning of WM, there are practical benefits that result from concentrating wastewater streams, including decrease disposal costs. Concentration may make a waste stream easier to recycle, and is also desirable if facility's current wastewater treatment system is overloaded. It may be practical, especially for operations not involving chemical reactions, to express WM indirectly in terms of the ratio of input materials consumption to production rate. These data are easier to obtain, although the measure is not direct. Measuring WM by using a ratio of waste quantity to material throughput or producer output is generally more significant for specific units or operations, rather than for an entire facility. Therefore, it is important to preserve the focus of the WM project when measuring and reporting progress (1).

It is important that WM principles be applied to new projects. It is easier to avoid waste generation during the research and development or design phase than to go back and change the process after it has already been installed. The earlier the evaluation is performed, the less likely it is that the projects will require expensive changes. All new projects should be reviewed by the WM program task force. A better approach than a pre-project evaluation is to include one or more members of the WM program task force on any new project that will generate waste. In this way, the new project will benefit from the "built-in" presence of a WM proponent and his/her input will promote a process design that will minimize waste. **Table 2.13** summarize the steps required to start a WM program. A helpful but not necessarily comprehensive WM checklist is presented in **Table 2.14.**

The WM program is ongoing, rather than a one-time effort. The frequency with which assessments are done will depend on the program's budget, fiscal period, and special controlling factors such as changes in raw materials or product requirements, new regulations, new technology, higher waste management costs, and major events (i.e. Spills or uncontrolled emissions) with undesirable environmental consequences. WM must be an indispensable part of the company's operations. The most successful WM programs to date have all developed this philosophy within their companies (1).

Table 2.13
Steps required to start a WM program (3)

1. Perform a WM study to find out what kind of waste the plant produces. Using a flow chart of the company's production processes, determine:

- The type of waste is generated at each point of the process.
- The quantity of each type of waste generated.
- Determine the reasons for their volume and presence.

2. Determine ways to reduce wastes at each step in the process. Thoughtful planning is critical to integrate WM into production practices.

- Identify alternative production strategies that will eliminate or at least reduce waste creation.
- Estimate the costs and benefits of each WM system.
- Select at least one alternatives that will meet WM goals.

3. Set achievable and measurable WM goals for the company.

4. Assign a WM coordinator.

5. Develop a personnel training program and encourage employee's involvement in WM program.

6. Make good WM effort a criterion for employee bonuses.

7. Develop cost-allocation system where:

- WM amount should be part of job performance evaluation.
- Departments are penalized/charged for wastes generated above a specified limit.

8. Evaluation of the program:

- WM data should be evaluated periodically to determine how successfully it is being implemented.
- Practices should be modified as necessary to attain program goals.

Table 2.14
WM checklist (3)

___ Identify waste generation points in the production or work process.
___ Determine quantities of each waste generation per specific time period (hour/day/month..).

___ Identify alternative ways that wastes can be reduced at each point in the process.
___ Develop WM goals with measurable objectives.

___ Evaluate the raw materials used for ways to reduce their toxicity and volume of disposal. This might mean using different raw materials that may be easier to reuse or recycle.

___ Evaluate options to reduce the environmentally damaging materials in the waste.
___ Develop decision criteria to determine optimal WM options.
___ Develop a plan which specifies WM objectives and sets targeted completion times for their accomplishment.

___ Evaluate efficiency of equipment and supply use. Efficiency can be increased by using materials that can be reused or recycled.

___ Evaluate investments in durable products and equipment which can be easily repaired and recycled.

___ Purchase recycled products.
___ Improve QC to improve efficiency.
___ Cooperate with supplier to reduce the amount of packaging they send.
___ Make your purchases in bulk quantity and ask vendors to eliminate unnecessary packaging materials.

___ Work with suppliers that will haul back their containers and packing materials.
___ Establish a company-wide commitment to make WM a part of everyday's business.
___ Establish a WM budget and make sure that resources are available.
___ An enthusiastic WM task force should be established.
___ Educate and train employees about WM practices.
___ Improve worker training to reduce rejects.
___ Check waste exchanges for materials that might be used as raw materials in production process.

2.4 Examples of Solid Waste Minimization Opportunities for Specific Industries

One of the strongest incentive to implement a WM program is the savings that comes with it. Less waste means: raw material cost savings, insurance & liability savings, decreased waste management costs, and operating cost savings from product QC. In this section, a general description of operations and summary of WM opportunities is presented for each of the three industry types: metal fabrication, metal casting, and heat treating

2.4.1 The Fabricated Metal Industry

2.4.1.1 General description of operations:

Four types of processes used in metal fabrication are investigated in this section; machining operations, parts cleaning and stripping, metal surface treatment and plating, and paint application. These processes use a diversity of hazardous materials, including metal-working fluids, solvents, alkaline and acid cleaning solutions, treatment and plating solutions that contain hazardous metals such as chromium and cadmium, as well as cyanide and other chemicals, and paints containing solvents and heavy metals. Many of those hazardous substances are being phased out in some applications, in favor of more benevolent compounds. There are two major segments of the industry: job shops that process materials owned by other parties on a contractual basis, and captive shops that are owned by and are part of larger manufacturing facilities (6).

Machining processes use some type of cutting tools. Most of the power exhausted in cutting is transformed into heat, the major portion of which is carried away by the metal chips, while the balance is divided between the tool and workpiece. Turning processes and some drilling are done on lathes, which hold and rapidly spin the workpiece against the edge of the cutting tool. Drilling machines are meant not only for making holes, but for reaming existing holes. This process is also carried out by reaming machines using multiple cutting edge tools. Milling machines also use multiple edge cutters, in contrast with the single point tools of a lathe. While drilling cuts a circular hole, milling can cut odd or irregular shapes into the workpiece. Broaching is a process whereby internal surfaces such as holes of circular, square or irregular shapes, or external surfaces like keyways are finished. A many-toothed cutting tool called a broach is used in this process. The broach's teeth are graded in size in such a way that each one cuts a small chip from the workpiece as the tool is pushed or pulled either past the workpiece surface, or through a leader hole. Broaching of round holes often gives greater freedom from errors and better finish than reaming (6).

Metalworking fluids are those liquids/gases that are applied to the workpiece and cutting tool in order to facilitate the cutting operation. They can be sprayed, air-blasted, drawn through suction onto the tool-workpiece interface. Types of fluids include water; emulsions of a soluble oil or paste; non water based oils such as sulphurized, mineral, or chlorinated oil. Air drafts are often used with grinding, polishing and boring operations to displace dust and chips, and to cool to a certain magnitude. Aqueous solutions containing approximately one percent by weight of an alkali exhibit high cooling properties and also provide corrosion prevention for some materials. Emulsions consist of a suspension of oil or paste in water, depending on the application. Rich mixtures of oil to water are used for broaching, gear cutting and threading, while a 1:20 ratio suffices for most lathe work, drilling and screw machine work (6).

The major wastes from machining operations are contaminated metalworking fluids which are treated as hazardous waste because of their oil content, as well as other chemicals additives that some contain. While fresh metalworking fluids contain varying degrees of oil depending on their function, '*tramp*' hydraulic and lubricating oils also find their way into the fluids during the course of operations. Spent metalworking fluids are at present disposed of or recycled on/off-site. Recycling typically consists of separating the oils through such methods as centrifuging and refining them or using them as fuel. Scrap that is impending reclamation is not regulated as hazardous waste. If metal chips from machining operations are mixed with hazardous metalworking fluid wastes, however, the waste stream is treated as hazardous (6).

Practically all fabricated metal objects require some form of cleaning. Machined parts are cleaned with solvents; paint oxidation and old plating is stripped from workpieces using caustics and abrasives; and workpieces in plating lines are cleaned several times using acid, water, caustics and detergents.

The types of metal cleaning media utilized by industry are: solvents, alkaline cleaners, acid cleaners, abrasive materials and water. Alkaline and acid cleaners are usually referred to as aqueous cleaners. Mixtures of solvents and alkaline cleaners are frequently used. Mixtures where a water-immiscible solvent is emulsified in water are termed emulsion cleaners. The design of a cleaning operation is generally dependent upon three interrelated factors- the nature of the contamination, the metal substrate, and the degree of cleanliness required.

The primary wastes associated with metal parts cleaning are listed in **Table 2.15**, along with their sources. If a facility has a wastewater treatment system, primary rinse water, alkaline and acid cleaning solutions can be mixed together and treated.

Table 2.15
Metal Parts Cleaning Wastes (6)

Waste Description	*Process Origin*	*Composition*
Abrasive	Removal of rust, scale polishing of metal	Silica metal, Aluminum oxide, water, and grease
Alkalines	Removal of organic soils & descaling	Water, organic soils, additives & alkaline salts
Acids	Removal of smut & scale	Acids, water, additives, dissolved metal salt
Rinse water	Removal of previous cleaning material	Water with trace of cleaners & additives
Solvents	Removal of oilbased soils	Halogenated & nonhalogenated solvents, oil-based contaminants

Secondary rinse water is usually used to replace discarded primary rinse water and /or used as a makeup for cleaning solutions. For facilities using small amounts of cleaner, the tendency is to drum the material for disposal. Solvent waste can be sent to an off-site recycler or recycled on-site using distillation equipment.

Metal surface treatment and plating are practiced by most industries engaged in forming and finishing metal products, and involve the modification of the metal workpiece's surface properties, in order to increase corrosion or abrasion resistance, modify appearance, or in some other way enhance the utility of the product. Plating and surface treatment operations are usually batch operations, in which metal objects are dipped into and then removed from baths containing various reagents for achieving the required surface condition. The processes involve moving the object to be coated through a series of baths designed to produce the desired end product. Workpieces can be carried on racks or in barrels. Large workpieces are mounted on racks that carry the parts from bath to bath. A set of small parts can be contained in barrels that rotate in the plating bath.

Most metal surface treatment and plating processes have three basic steps - as surface cleaning or preparation, the actual modification of the surface involving some change in its properties, and rinsing or other workpiece finishing operations (6).

Chemical and electrochemical conversion treatments are designed to deposit a coating on a metal surface that performs a corrosion protection and/or decorative function, and in some instances is a preparation for painting. Processes include phosphating, chromating, anodizing, passivation and metal coloring.

Case hardening produces a hard surface over a metal core that remains relatively soft. Case hardening methodologies include carburizing, carbonitriding, nitriding, microcasing, and hardening using localized heating and quenching operations.

Applied energy methods are those that generate a case through localized heat and quenching, rather than through use of chemicals. Very rapid heat application results in surface hardening with little heat conducted inward. Metallic coatings indicate diffusion coatings, spraying techniques, cladding, vapor deposition and vacuum coating. Hot dipping is a diffusion process that involves partial or complete immersion of the workpiece in a molten metal bath. Common coating materials include aluminum, coated lead, tin, zinc, and combinations of the above (6).

Electroplating is accomplished by passing an electric current through a solution containing dissolved metal ions as well as the metal object to be plated. The sequence of unit operations in an electroplating operation is very similar when either racks or barrels are used to carry parts. Electrodeless plating uses similar steps, but involves the deposition of metal on a metallic or non-metallic surface without the use of external electrical energy.

Two of the waste streams, spent acid cleaning and spent alkaline cleaning solutions, are generated by periodic replacement of contaminated solutions. Rinse waters are generated from overflow of rinse tanks and contamination by drag-out from cleaning baths. Waste removed from plating tanks by the continuous filtering of the baths results in filter sludges (6).

Waste produced at a particular facility will be similar to those listed, but their precise composition will depend on the specific process. Contaminated rinsewater accounts for the majority of plating process waste. Drag-out refers to the excess solution that adheres to the workpiece surface and gets carried out of the solution bath upon withdrawal of the workpiece from the bath. If the drag-out from one bath is carried into the next bath in the sequence due to inadequate rinsing, it is referred to as "drag-in", and is considered a contaminant in the latter bath.

Spent cleaning and plating solutions are another source of plating wastes. Several types of cleaning solutions are used to prepare a metal surface for electroplating. Stripping wastes are a special type of cleaning waste. They result from the stripping off of the old plated deposit prior to the deposition of a new metal plate. These solutions are not regularly discarded like cleaning solutions, but may require cleansing if impurities build up.

Wastes produced from spills and leaks are usually present to some extent in an electroplating process. Water is used to wash away floor spills, and the resulting wastewater contains all of the contaminants present in the original solutions. Wastewater is also produced from the wet scrubbing of ventilation exhaust air. Wastewater produced in an electroplating process may contain a diversity of heavy metals and cyanide. The metals are typically removed by adding lime or other precipitating agents, and precipitated under alkaline pH. The resulting metal hydroxide precipitate forms a dilute sludge, which is thickened and then disposed of by landfilling. Most paint coatings for fabricated metal products are solvent based although many shops are replacing these with water based materials (6).

Before a product coating can be applied to a surface, the surface must be free from contamination. Once a part is cleaned, surface treatment such as phosphate coating can be applied if desired. When it is desired to paint a large number of very small items, the most commonly used methods are tumbling, barreling, or centrifuging. For all three methods, the parts are placed inside a barrel, solvent-based paint is poured onto the items, and the barrel is then rotated. After a short time and at the correct point of tackiness, the parts are transferred to an oven in a wire basket. While paint consumption using these methods is very small, the empirical nature of the operation requires that the operator be highly experienced to accomplish reliable results. Many complex items can be dip painted provided that drainage points can be located where they are not visible.

Flow coating is often utilized for items that would be difficult to dip because of their size or shape, or as a method of avoiding the installation and operation of large dip tanks. A flow coating system operates by using high pressure sprays to flood the item with solvent-based paint. After spraying, the item is allowed to drain and the excess paint is recirculated. Since a substantial amount of bubbling occurs due to spraying, the item is then passed through a solvent chamber where the solvent vapors allow the paint to reflow. Succeeding this operation, the item is then oven-dried. The main disadvantage of flow coating is high solvent loss, which can be three times as large as for dipping and twice as great as for spraying (6).

For somewhat flat items of large area, roller coating and curtain coating machines are used. A curtain coating machine consists of a pressurized container along the bottom of which is an adjustable slit that allows the coating to flow and form a vertical curtain. A conveyor belt is placed on each side of the curtain so that work items are passed through the curtain and coated without the conveyor belts being coated.

A spray gun operates by using compressed air, to atomize the paint and produce a fan-shaped or circular cone spray pattern. By eliminating the use of compressed air, operating costs are lower, spray mists are not produced, and expensive exhaust systems are not required. Electrostatic spray units are designed so that the atomized paint exiting the gun has a positive charge. This positive charge causes the paint to be attracted to the object which is connected to ground. Since more of the paint reaches its target, less waste is generated (6).

Following the application of paint, the item is passed through a drying or curing oven. Once dried, the items are sent to inspection and final packaging or assembly. If a part fails inspection because of a bad finish, it is usually reworked by stripping off the paint and returning it to the cleaning operation. The primary wastes associated with product coating applications consist of empty paint containers, spent cleaning solutions, paint overspray , spent stripping solutions, and equipment cleaning wastes (6).

2.4.1.2 WM & Recycling for Fabricated Metal Product Facilities:

Good operating practices are defined as procedures or institutional policies that result in a reduction of waste. The following describes the scope of good operating practices:

- Waste stream segregation.
- Personnel practices: Management initiatives and employee training.
- Loss prevention practices: Spill prevention, preventive maintenance and emergency preparedness.
- Procedural measures: Documentation, material handling and storage, scheduling, material tracking and inventory control.

Efficient operating practices can reduce or eliminate waste resulting from oldness and improper storage. Source reduction methods for reducing waste include:

- Material Preinspection: This prevent both disposal of a nearly full container of unusable material.
- Proper Storage of Materials: Chemical containers list the endorsed storage conditions. Meeting these conditions will increase their shelf life.
- Restrict Traffic through Storage Area: To hinder raw material contamination. Also, the storage area should be closed to through traffic.
- Inventory Control: Using the "first-in, first-out" practice. Computerized inventory systems can track the amounts and ages of the raw materials.
- Purchase Quantities According to Needs: Large shops should order materials in large containers, which may be returnable, thereby eliminating or reducing the need to clean them.
- Test Expired Material for Usefulness: A recycling channel should be found for left over raw material that is no longer wanted (6).

While the best solution for tramp oil problems is to stop the oils from entering the metalworking fluid, some pollution will occur as the machines and their oil seals and wipers wear. Optiomal metalworking fluid performance starts with a preventive maintenance program that includes:

- Control of fluid chemistry (pH, dissolved oxygen, etc.).
- Use of high quality, stable cutting and grinding fluids.
- Use of demineralized water for mixing purposes.
- Fluid concentration control and contamination prevention.
- Assignment of responsibility for fluid control to one person.
- Periodic sump and machine cleaning and regular cleaning of metalworking fluid through filtering or centrifugation, in order to minimize microbe growth by controlling tramp oil buildup.
- Periodic gasket, wiper and seal inspections and replacements to minimize tramp oil contamination.

The two most important source reduction targets for solvent waste are to minimize evaporation vapor loss and to maintain solvent quality. In addition, substitutions of hazardous solvents with other media is often a very effective means of source reduction. Measures that are determined helpful in maintaining quality and minimizing vapor loss include:

1. Installation of lids on tanks.
2. Increase in freeboard space.
3. Installation of freeboard chillers in addition to cooling jackets.
4. Avoidance of cross-contamination of solvent.
5. Avoidance of water contamination.

6. Prompt removal of sludge that collect in the bottom of tanks.

7. Using appropriate make-up solutions for the solvent bath.

8. Using a minimum number (preferably one) of types of solvents in all operations in the plant.

9. Consolidating operations into a centralized vapor degreasing procedure.

Other waste reduction methods based on better operating practices include locating cold cleaning tanks distant from heat sources, controlling the amount of heat supplied to vapor degreasers, avoiding spraying parts above the vapor zone of cooling jacket, and avoiding solvent vapor drag-out (6).

On site recycling of solvent is recommended to reduce transportation liabilities and is found to be economical when at least 8 gallons of solvent waste is generated per day. **Table 2.16** present the evaluation of on-site recycling. Some of the most commonly used on-site recycling techniques are: Gravity separation, Filtration, Batch & Fractional distillation, and Fuel use. Abrasive powders are commonly mixed with an oil-based or water-based binder and are then applied to a polishing /buffing wheel. The following source reduction methods are applicable for abrasive cleaners:

1. Use of greaseless or water-based binders for polishing/buffing because it leaves the buffing wheel clean and dry. Moreover, adhere well to the surface of the wheel, extending wheel life.

2. Use of liquid spray compositions. A spray gun applies the composite to the wheel automatically. Moreover, since spray compounds are usually water-based, there should be no need for following cleaning due to burned binder material deposits on the workpiece.

3. Cautious control of water level in mass finishing equipment.

4. Synthetic abrasives are sometimes achieved by putting both workpieces and abrasives grit into a tumbling barrel and rotating until the parts are finished. Beach sand and river rocks are frequently used as abrasives. These will grind down, after all, into a great volume of fine silts mixed with metal fines that must be treated as a hazardous waste. This problem can be reduced by using aluminum oxide grit in place of beach sand, and ceramic abrasive deburring material in place of river rock.

Table 2.16
Evaluation of on-site recycling (6)

Advantages	*Disadvantage*	*Reported difficulties*
Less waste leaving the facility	Capital outlay for recycling equipment	Loss of solvent during distillation process
Owner control of reclaimed solvent's purity	Liability for worker health, explosions, fire, leaks, spills, and other risks as a result of proper equipment operation	Low Solvent recovery efficiency
Reduced manifesting	Possible need for operator training	Installation problems
Lower liability	Additional operating costs	Maintenance problems
Possible lower units cost of reclaimed solvent		

Some source reduction methodologies for surface treatment and plating wastes are:

- Process Solutions: These require periodic replacement due to contamination build-up or the loss of solution constituents by drag-out (6). The source control methods available are:

  Increasing solution life: Proper design and maintenance will minimize this form of contamination. The use of purer metal for anodes also prolong the plating solution life. Effective rinsing of the workpiece between different plating baths reduces the carryover of plating solution into the next bath. Utilizing demineralized or distilled water as makeup to compensate for evaporation is favored over tapwater, since tapwater may have high minerals or solids contents, which can lead to contamination buildup. Periodic filtering is used to keep levels of residue low. Continuous or daily rotation of plating baths through carbon or small hole filters have dramatically prolonged bath life by cutting sludge buildup, which inevitably would impair plating quality.

Material substitution: Replacing cyanide solutions with non-cyanide solutions, nonetheless, often requires upgrading of the degreasing/cleaning techniques used, because the non-cyanide replacements may require a thoroughly cleaned surface to ensure high quality plating. Replacement of cadmium-based plating solution is practicable in many applications. Replacement of hexavalent chromium with trivalent chromium offers important environmental advantages. Because there can be a considerable amount of highly toxic waste produced during a chromium plating procedure, the elimination of any redundant use of chromium would be beneficial from the environmental perspective.

Process substitution : Hot dipping of tin and other metals, for example, in which the workpiece is submerged in a liquefied metal bath, could furnish a way of reducing toxic effluent levels.

Chemical coatings: Chemical vapor discharge is the gas-phase analog of electroless plating, in that it is catalytic and involves a chemical reduction of a species to a metallic material which forms the coating.

Mechanical cladding and coating: The 3M Company has developed a cold welding technique in which the workpiece, the metal powder, water, glass shot and additives are tumbled together in a barrel. The procedure is suitable only for small parts, and it does not produce a fine surfaced, cosmetic coating.

- Waste Rinsewater: Great amounts of rinsewater are utilized to rinse off drag-out on a metal surface after the metal is removed from a plating of cleaning bath. There are various methods available to reduce the amount and/or toxicity of waste rinsewater produced. These methods can be grouped into two techniques:

    - **A.** Drag-out minimization : This is not effective unless accompanied by a ways of cleansing the bath of residues that build up and that otherwise have no outlet.

Drag-out minimization techniques typically include:

- *Reducing the speed of withdrawal of workpiece from solution and allowing ample drainage time*: Usually, 30 seconds allows most of the drag-out to drain back to the tank.

- *Lowering the concentration of plating bath constituents.*

- *Use of surfactants* : is sometimes limited due to their secondary result on the quality of the plate produced.

- *Increasing plating solution temperature.*

- *Proper positioning of the workpiece on the plating rack*: The position of any object which will decrease the carry-over of drag-out is best decided on a trial basis, although the following guidelines were found to be effective:
    1. Position the surface as close to vertical as possible.
    2. Rack with the longer dimension of the workpiece horizontal.
    3. Rack with the lower edge tilted slightly from the horizontal so that the runoff is from a corner rather than an entire edge.

- *Improved drag-out recovery*: A drain board positioned between a plating bath and rinse bath can capture the solution dripping from a workpiece and route it back to the plating bath. Another option is to include a drip tank between the plating bath and the rinsing bath. A third alternative is the use of a still rinse tank with components periodically returned into the plating (6).

B. Rinsewater: The aim of rinsewater minimization is to use the least volume of water needed to sufficiently clean the workpieces. Several system design methods exist for lowering rinsewater requirements, including:

- *Rinse tank design*: The most significant factor in the design of rinse tanks is ensuring full mixing of rinsewater, thus eliminating short circuiting of feed water and employing the entire tank volume.

- *Multiple rinsing tanks.*

- *Reactive rinsing.*

- *Fog nozzles and sprays.*

- *Automatic flow control.*

- *Rinse bath agitation.*

- Treatment Wastes: The toxicity and volume of the sludge created can be minimized by reducing the metal content in the plating and rinse waters, or by using unconventional precipitating agents. Methods available to achieve this include :

  A) *Utilization of different precipitating agents and other treatment chemicals*: Sodium hydroxide precipitation agents generated 12 percent fewer dry solids than lime precipitation. Caustic soda utilized as a neutralizer and precipitation agent can in some situations generate up to 90 percent fewer sludge than using lime. Polyelectrolyte conditioners do not have the same sludge contribution as alum and ferric chloride.

  B) *Utilization of trivalent chromium in lieu of hexavalent chromium for plating* avoided the necessity of precipitating gypsum associated with surplus sulfate ions introduced during the reduction step.

  C) *Waste segregation* : Segregation of wastewater streams having different metals also allows for metals recovery/reuse.

  D) *Higher sludge dewatering efficiency*: These involve effective filter presses and thermal and air-drying techniques that can reduce the sludge to a nearly-dry cake (6).

- Source Reduction for Other Types of Metal Surface Treatment: Source reduction for case hardening operations recurrently involves selecting cleaner processes. Another potentiality is to shift to applied energy hardening methods that produce a case through localized heating and quenching, sans use of chemicals. It is the present carbon content of the metal that eases the hardness response when heated.

Some of the recycling and resource recovery technologies available to the metal finishing industry are:

- Waste Material Reuse: Successful recycling requires a change on the part of management and plant staff, to view their waste streams as resources, rather than as something to be thrown away. The drag-out film on the workpieces coming from the alkaline bath is alkaline. Recycled water from acid bath rinses has an acid pH, and thus tends to neutralize the drag-out film. This reduces its viscosity and accelerates the rinsing process. Acid cleaning rinse water effluent can be used as rinsewater for workpieces that have gone through a mild acid etch process. Effluent from a critical or final rinse operation, which is generally less contaminated than other rinse waters, can be used as influent for rinse operations that do not require high rinse efficiencies. Another choice is using the same rinse tank to rinse parts after both acidic and alkaline baths. Spent process baths can also be reused as pH adjusters (6).

Metal Recovery and Water Reuse: Many systems may not be economically practicable for small surface treatment and plating operations because the capital expenses of installing the necessary equipment might outweigh the saving from recovering process chemicals. Metal recovery can be achieved in two ways: (1) Recovered metal salts can be recirculated back into process baths, or (2) Recovered elemental metal can be sold to a metals recyclers or reused in the plating process. Methods for recovering process chemicals and rinsewater from rinsewater effluent include evaporation, reverse osmosis, ion exchange, electrolytic recovery, and electrodialysis.

Some of the source reduction methodologies for paint wastes are:

- Empty containers: Source reduction methods for this waste stream include:

A) *Waste segregation.*

B) *Bulk purchasing.*

C) *Minimizing residuals*: While the per unit cost of paint when purchased in various small amount containers is greater than the cost of paint when purchased in larger quantities, the savings in reduced paint wastage and disposal costs could still be substantial.

- Paint Application Waste: Use of paint application equipment with low overspray characteristics. The following are efficiency ranges for several different spray systems:

Spray Method	*Efficiency*
Conventional air-atomized	30 - 60%
Conventional pressure-atomized	65 - 70%
Electrostatic air-atomized	65 - 85%
Electrostatic centrifugally-atomized	85 - 95%

Other types of equipment that can yield even higher efficiency values are roller and flow coating machines (90 to 99 percent). Nevertheless, they are limited in their suitability based on the shape of the parts. Electrocoating systems require a shift from solvent-based to waterbased paint (6).

- Operator Training: The equipment operator has a significant effect on the amount of waste produced. When air pressures are set too high, the paint has a likelihood to bounce off the surface and increase overspray. The habit of arching the spray gun in lieu of keeping it perpendicular to the surface effects the overspray; when the gun is arched 45 degrees away from the surface at the end of each stroke, overspray can be enormous and an uneven coat of paint can follow. By maintaining all application equipment in good working order, the probability of producing a bad finish is lessened.

Spray guns should be cleaned after use whenever there will be an appreciable interval between use.

- Material Substitution: In order to decrease the quantity and toxicity of waste paint requiring disposal, new coating types have been developed which eliminate the hazardous components of the paint and also allow for maximum reuse of paint application process. These alternatives include:

  A) *Water-based coatings*: No major equipments changes are necessary. Overspray from a waterbased coating can be collected/captured with water in the spray booth. This system also reduce hazardous waste disposal, personnel and maintenance costs by 40 percent.

  B) *Radiation-curable coatings*: Reactive monomers are utilized as liquid to surface which is then exposed to high energy radiation such as UV or infrared light. The benefits of using this coating methodology include the decline in waste from solvent loss and a decline in energy and maintenance requirements.

  C) *Powder coatings (Dry painting)*: Manually, the powder is sprayed on the object and the overspray is easily retrieved and recycled, something that is very difficult to do with liquid paints. Overspray and other unused powder are returned to the feed hopper for reuse.

Paint applying equipment is often cleaned with solvents. Cleaning wastes can occasionally be recycled (6).

2.4.2 Metal Casting Industry

2.4.2.1 General operations:

Metal casting foundries have a wide range of sizes. The technology employed and the types of materials, molds and cores used dictate the amount of waste generated. Permanent mold or die casting produces less waste than sand casting. **Table 2.17** summarizes sources of metal casting wastes.

Table 2.17
Metal casting wastes (7)

Process	Waste
Molding & Coremaking	Spent sand, core butts, Dust & sludge
Melting	Dust & fumes Slag
Casting	Investment casting, Shells & waxes
Cleaning	Cleaning room waste

A pattern is a specially made model of a component to be fabricated. Sand is placed around the pattern to make a mold. Molds are usually fabricated in two halves so that the pattern can be easily removed. When the two halves are reassembled, a cavity remains inside the mold in the shape of the pattern (7).

The molds used in sand casting consist of sand that is bonded together to hold its shape during pouring. The most common type of molding process is green sand, which is typically made of sand, clay, carbonaceous material, and water. A wide variety of binders are available, including: alumina-phosphate no-bake binder, ester-cured alkaline phenolic no-bake binders, furan acid catalyzed no-bake binders, hot box binders, novolac shell-molding binders, oil urethane no-bake resins, phenolic urethane no-bake (PUN) binder, phenolic acid catalyzed no-bake binders, polyol-isocyanate system, silicate/ester-catalyzed no-bake binders, and warm box binders.

The metal casting process starts with melting metal to pour into foundry molds. Once the molten metal has been treated to achieve the desired properties, it is transferred to the pouring area in refractory-lined ladles. Slag is removed from the bath surface and the metal is poured into molds. When the poured metal has hardened and cooled, the casting is shaken out of the mold, and the risers and gates are removed. Fumes or smoke from the metal pouring area are typically exhausted to a dust collection device such as a baghouse (7).

After mechanical cleaning, the metal casting is blast cleaned with abrasive particles, usually steel shot or grit, which are propelled at high velocity onto the casting surface to remove surface contaminants. High-carbon steel shot is typically used to clean ferrous castings. Cast components that require special exterior characteristics may be coated. The most important prerequisite of any coating process is cleaning the exterior, which depends on the types of residue to be dislodged, and the characteristics of the masking to be applied. If castings are heat treated before they are coated, the choice of heat treatment conditions can affect the properties of the coating, particularly a metallic or conversion coating. Molten salt baths clean faster than other non-mechanical methods, but castings may crack if they are still hot when salt residues are rinsed off with water (7).

Parts are usually pickled in an acid bath prior to hot dip coating or electroplating. Over-pickling should be avoided because a graphite smear can form on the surface. Alkaline cleaner must penetrate contaminants and wet the surface to be effective. Organic solvents commonly used in the past have been largely replaced by chlorinated solvents, such as those used for vapor degreasing. Emulsifiers are solvents combined with surfactants; they scatter contaminants and solids by emulsification. Castings are coated using plating solutions, alloys, powdered metals, molten metal bath, volatilized metal or metal salt, phosphate coatings, porcelain enamels, and organic coatings. Product castings manufactured by foundries generate the following wastes:

1. Miscellaneous Waste: This waste includes welding materials, empty drums of binder, waste oil from forklifts and hydraulics, and scrubber.

2. Investment Casting Waste (i.e. shells and waxes)

3. Cleaning Room Waste

4. Dust collector and Scrubber Waste

5. Slag Waste

Spent foundry sand: Most foundries reuse some part of their core making and molding sand; in many cases most of the sand is reused. Green sand is reused repeatedly. Fines build up as sands are reused, and a certain amount of system sand, combined with the sand lost to spills and shakeout, becomes the waste sand. Waste can also be in the form of large clumps that are screened out of the molding sand recycle system or in the form of sand that has been cleaned from the castings. Core sand binders either incompletely or completely degrade when exposed to the heat of the molten metal during the pouring operation. Once loose, sand that has had its binder completely degraded is often mixed with molding sand for recycling or is recycled back into the core sand process. Core butts are slightly decomposed core sand removed during shakeout. The core butts can be crushed and recycled into the molding sand process, or may be taken to a landfill along with broken or "offspec" cores and core room sweepings. Molding sand and core sand waste account for 66-88% of the total waste generated by ferrous foundries (7).

2.4.2.2 WM opportunities for baghhouse dust & scrubber waste:

A) *Source reduction and recycling opportunities for several materials in casting industries:*

1. Alter Raw Materials: A charge modification program at a large foundry can successfully reduce the lead and cadmium levels in dust collector waste to below USEPA toxicity values.

2. Install Induction Furnaces: this emits about 75% less dust and fumes because of absence of combustion gases or excessive metal temperatures.

3. Recycle to the Original or Outside the Original Process:

    - Pyromettallurgical Methods
    - Rotary Kiln Technology
    - Zinc Oxide Enrichment
    - Electrothermic Shaft Furnace

4. Recycle to Cement Manufacturer.

B) *Hazardous desulfurizing slag*:

In the making of ductile iron, it is often necessary to add a desulfurizing agent in the melt to produce the desired casting microstructure. Calcium carbide is often used and is thought to decompose to calcium and graphite. The calcium carbide desulfurization slag is usually extracted from the molten iron in the ladle and placed into a hopper. For adequate sulfur removal, calcium carbide must be added in slight excess. Therefore, the slag contains both CaS and CaC_2. Since an excess of CaC_2 is employed to ensure removal of the sulfur, the resulting slag must be handled as a reactive waste. The slag might also be hazardous due to high concentrations of heavy metals. There are several options to handle this problem such as (7):

1. Alter feed stock.
2. Use a different desulfurization agent such as calcium oxide and calcium fluoride.
3. Alter product requirements.
4. Improve process control.
5. Recycle to process or other lines.

C) *Spent casting sand:*

In most foundries, casting sands are recycled internally until they can no longer be used. At that time, many of the sands, such as those from iron foundries, are landfilled as nonhazardous waste. The overall amount of sand being discarded can be significantly reduced by implementing the following waste segregation steps:

1. Replumbing the dust collector ducting on the casting metal gate cutoff saws to collect metal chips for easier recycling.
2. Detoxifying sand that remains useless as a result of size reclassification after sand reclamation.
3. Changing the core sand knockout procedure to keep this sand from being mixed in with system sand prior to disposal.
4. Installing a magnetic separation system on the shotblast system to allow the metal dust to be recycled.
5. Installing a new screening system on the main molding sand system surge hopper to constantly clean metal from the sand system.
6. Installing a new baghouse on the sand system to separate the sand system dust from the furnace dust (7).

Most foundries utilize several different screen types and vibrating mechanisms to break down large masses of sand mixed with metal chips. Coarse screens are used to remove large chunks of metal and core butts. The large metal pieces compiled in the screen are usually remelted in the furnace or sold to a secondary smelter. Increasingly fine screens remove additional metal particles and help categorize the sand before it is molded. Some foundries remelt these smaller metal particles; other foundries sell this portion to metal reclaimers. The metal recovered during the screening procedure is often mixed with coarser sand constituents or has sand clinging to it. Therefore, remelting these pieces in the furnace generates large amounts of slag, especially when the smaller particles are remelted (7).

To reclaim brass metal and sand, the sand is processed to physically remove as much of the brass metal as possible. This material has relatively high value, and constitutes from one-half to two-thirds of the heavy metal in the sand. The physical separation processes include gravity separation, magnetic separation units, and size screening. The second stage of the process removes the heavy metals found in the fines and the coatings from the sand. The chemical processes consist of mineral acid leaching, followed by metal recovery. Sand could be reclaimed by attrition/scrubbing, and thermal systems. In the reclamation of chemically or resin bonded sands, the system employed must be able to break the bond between the resin and sand and remove the fines that are generated. The systems most commonly employed are wet washing and scrubbing for silicate-bonded sands, or dry scrubbing/attrition and thermal systems for resin-bonded sands (7).

Sand could be utilized as a construction material. The University of Wisconsin in Madison has performed a substantial amount of research on the suitability of using spent foundry sand as a substitute cover and fill raw material. This research showed that:

- Physical properties of foundry sand are suitable for use as road fill material.
- None of the samples leached would be defined as hazardous by RCRA identification criteria.
- Foundry sand leaching characteristics varied little over time and among different waste streams within a given foundry.
- The leaching tests showed commonly low release of all parameter tested, most at concentrations below drinking water standards.

Bituminous concrete (asphalt) is another potential reuse market for foundry waste. Spent sand would provide silica, and slag would provide quicklime and silica. AFS Research has discovered that use of spent foundry sand in cement manufacturing results in increased compressive strengths over control mixes. This effect increases with the addition of foundry sand. It also found that using spent foundry sand as a substitute fine aggregate material in the manufacturing of concrete results in decreased compressive strengths when green molding sand are used (7).

2.4.3 Heat Treating Industry

2.4.3.1 General operations:

Heat treating refers to the heating and cooling operations performed on metal workpieces to change their mechanical properties, their metallurgical structure, or their residual stress state. It includes stress-relief treating, annealing, austenitizing, austempering, normalizing, matempering, hardening, quenching, tempering, and cold treating. **Table 2.18** lists the waste characteristics of various generating processes in heat treatment.

Table 2.18
Characteristics of waste from heat treatment processes (7)

Process	Waste
Heat Treating	Refractory material
Case Hardening	Spent salt baths
Cleaning & Masking	Solvents, abrasives Copper plating waste
Descaling	Spent abrasive media

Spent cyanide baths, spent quenchants, wastewater generated in parts cleaning operations, spent abrasive media, refractory material, and plating generate the most waste in heat treating industry. The following is a description of wastes for the processes involved:

1. Case Hardening Baths and Salt Pots: In normal bath maintenance routines, sludge is usually spooned from the bottom with a perforated dipper. In liquid carburizing, sludge is removed while the furnace is still at idling temperature. The electrodes of internally heated furnaces are scraped clean. As the bath media is exhausted, bath pots corrode. To minimize corrosion of the pot at the air-salt interface, salts are completely changed every three or four months.
2. Quenching: Waste is generated in the following form:

    - Quenching process drag-out from other than case hardening processes.
    - Salt sludge from oil baths used for quenching cyanided and liquid carburized and nitrided parts.
    - Spent water and brine quenchants used for liquid cyanided, liquid carburized, and liquid nitrided parts.

3. Parts Cleaning and Masking: The most popular masking operation is copper plating.

2.4.3.2 WM opportunities:

A) *Case hardening baths and salt pots:*

Oxidation products in cyanide-containing bath media, which is continuously used in case hardening processes, deplete the activity of the bath which then becomes hazardous waste. The following options are available to reduce bath and salt pot waste:

- Change bath composition.
- Clean all work placed in the bath.
- Use graphite cover on a cyanide bath.
- Dry work completely prior to liquid case hardening.
- Remove impurities.
- Minimize drag-out.
- Replace pot lining.
- A number of alternate technologies can be utilized to minimize or totally eliminate hazardous waste in the heat treating industry. These include plasma nitriding, induction heat treatment, and ion carburizing.

B) *Quenchant wastes:*

There are several options for WM of quenchant waste:

1. Minimize drag-out of quenchant & molten salts.
2. Utilize modified materials (i.e. additives).
3. Control temperature of oil quenchant.
4. Desludge quenchant oil by the frequent removal of the following contaminants:

- Metal oxides, sand & other insoluble solids, precipitated salts from case hardening baths.

- Carbonaceous materials that may be products of oil oxidation or carbon fallout encountered in protective-atmosphere installation.

5. Water should be removed from quenching oil bath by:

   - Allowing the water to settle and draining it off.

   - Passing the bath through a centrifuge.

   - Raising the temperature above the boiling point of water.

6. Ultrafilter water-polymer quenchants (7).

CHAPTER III
EXPLANATION of WORK

As indicated in the introduction, MCSWMD is involved with a two-year pilot project to minimize the amount of waste generated within its boundaries. This project is targeting individuals, local governments, institutions, and businesses. This effort is successful under the combined support of USEPA and Keep America Beautiful, Incorporated.

The MCSWMD is currently working with YSU-TDC to increase the competitiveness of the county's manufacturing community. The YSU-TDC has been performing free industrial WM audits for cooperating companies since March of 1994. This type of confidential waste audit is designed to assist companies in identifying WM options. However, it carries no guarantee that significant waste reductions will be achieved. Options are presented as recommendations where several options for WM exist.

The WM audit team initially sends a solid waste survey to the interested company to get an impression of the amounts and types of waste generated by the company. Upon receiving the results of this mailing, the team schedules an in-plant process audit and trash sort. These are information gathering tools to identify potential options for WM at the company. At that time, any additional questions regarding solid waste generation or management are presented. Then, WM options for the predominant waste streams are researched and a second visit is conducted to study the possible effects of these WM options on the company's production. Next, the general results and recommendation of this WM audit are presented in a meeting with the company's official. A written report is also prepared by the YSU-TDC. It is totally up to the individual company to decide what options are best suited for implementation based on the available personnel and financial situation of the company.

The written waste audit reports served as the starting point for this project. Upon receiving the YSU-TDC waste audit report, it was reviewed in detail, and a list of further questions was prepared. The questions were divided into two categories:

- Clarification of waste audit results and current operation.
- Clarification of waste minimization opportunities.

A memo with the list of questions was sent to the YSU-TDC for their review. At that point, a meeting was scheduled with the waste audit team leader for each project to further discuss the answers to these questions. The main goal of this meeting was to get a clear understanding of the waste steam. Upon receiving answers to as many questions as possible, a brief summary of the waste already being recycled and the recycling options identified in the waste audit was prepared. A preliminary decision tree was then developed and made available for critique by the YSU-TDC. After incorporating these additional comments, the decision tree was then finalized.

CHAPTER IV
IMPLEMENTATION

For every company discussed, company background information is presented followed by a summary of YSU-TDC waste audit findings and the author's questions and additional information from the interview with the YSU-TDC team leader. Finally the decision maker's flowchart is presented. Since the audits are confidential, the actual names of the companies are not provided.

4.1 General Considerations:

Certain preliminary steps are necessary for any industry to undertake a WM effort. These include developing a commitment from management and staff, selecting a WM planning team, and characterizing the waste stream. In addition, every decision maker should be willing to consider recycling options that should be implemented no mater what type of product the company produces. **Table 4.1** presents these considerations.

4.2 Company A:

Company A is a SIC Code 3479 company with a 17,000 square foot facility located in Northeast Ohio . It employs approximately 16 day-turn and 11 afternoon employees in the production department. It also employs 18 people in the administration department. The company provides custom metal etching and screen printing for a wide variety of decorative and product identification applications, and is a member of the National Association of Graphic and Product Identification Manufacturers. Stainless steel, anodized aluminum, brass, polycarbonates and polyvinyl are the major raw materials used in production. Company A shares the building and two 8 cubic yards paper and corrugated cardboard dumpsters with a neighboring company (9).

Table 4.1
Recycling options that should be implemented

1. Are you and the company management and staff committed to undertaking a WM effort ? If the answer is No consider steps to develop the necessary commitment. 2. Have you selected a team to implement the WM effort? If No, this is essential to do first. 3. Do you know how much waste is being generated and what type it is ? If No, perform a waste audit. 4. Have you implemented general recycling practices at your facility ? Examples include but are not limited to: utilizing washable rags versus paper towels, reusing paper in the form of shred for packaging, using reusable versus disposable, purchasing recycled and recyclable items, removing the company name from junk mail list, purchasing of supplies in bulk and concentrated forms, copying on both sides, strategically placing recyclable bins thorough the property, reusing/returning to supplier/compacting/ recycling of corrugated papers, providing employees with reusable mugs, converting scrap papers into memo pads, using two-way envelopes, purchasing reusable printer ribbons and cartridges, using electronic mail/bulletin board/routing of memos or publications, and using a plain paper fax machine.

4.2.1 YSU-TDC Findings:

A YSU-TDC audit team conducted an in-plant audit on January 23, 1995. On February 2, 1995, the team performed a sort of company A and its neighboring company's combined trash. The findings of the trash sort were: 15% Corrugated cardboard, 24% Tissue paper, 30% Solvent soaked rags, 3% HDPD film, 3% LDPD film, 4% Polypropylene, 2% Aluminum, 2% Steel cans, 1% Brown glass, 10% Pallets, and 1%

Other material. These percentages were the backbone of the YSU-TDC report. The following are the primary WM opportunities identified:

1. Recycling of corrugated cardboard: approximately $1600 per year can be saved by merely designating one of the dumpsters (twice a month pickup) as a corrugated only container.

2. Reusing/recycling of a neighboring company's paper shreds: approximately $7400 could be saved by using the neighboring company's paper shreds instead of Styrofoam peanuts purchased by company A. This will eliminate the cost of dumpsters, but require a minimal cost for storage bins.

3. Recycling of office paper: around 30% savings over conventional ways of disposal. Totes and bins for paper recycling are offered by local waste company.

4. Recycling of wood pallets: a minimum of 200 reasonably good 48x40 inch pallets could be purchased and picked-up by a recycler at roughly $1.50 each.

5. Purchasing of 55 gallon black paint drum containers: could save approximately $80 per year.

6. Using landerable shop towels versus disposable wipes.

7. Increasing production efficiency to minimize metal scrap: large amounts of wasted metal result from certain orders due to sizing difficulties.

8. Employing water based paints: could assist the company in hazardous and solid WM.

9. Recognize WM opportunities: by offering an employee incentive program where bonuses or other compensations are provided for cost savings attributed to WM efforts originated by employees (9).

4.2.2 Questions and additional information from interview:

On March 30, 1995 a memo was sent to YSU-TDC requesting clarifications of several issues related to WM at company A. Questions and answers, if available, are listed below:

A) *Clarification of Waste Audit Results & Current Operation*

1. Is the present recycling company the cheapest & most feasible way to handle scrap metals? It is my recommendation that a competitive bid should be done.
2. Why was the trash audit done on *COMBINED* refuse of company A & the neighbor's company? Both share the same dumpsters, so separation was not practical.
3. What is the cost of shipping F.O.B. company A for the paper shreds from a neighbor company ? Minimal.
4. The $7,400/yr. saving was based on the elimination of two dumpsters currently dedicated to paper shred disposal. Why wasn't the cost of the Styrofoam peanuts factored in the saving ?
5. What is the cost of storage bins F.O.B. company A?
6. Can the office paper be shredded and used in conjunction with other papers ?
7. Does the company make any "*Cutting List*" prior to manufacturing ?
8. Does the company sequence its big jobs into small sequences, where it can mix & match sequences for maximum efficiency ?
9. How do the two companies share the cost of recycling ?
10. What percentage of the combined recyclable material comes from company A (i.e. pallets, corrugated cardboard) ?
11. Does the process require epoxy paint ? Is it available with water base ? How much savings could be achieved by the switch ?
12. How much recyclable metal was found in the dumpster ? Is it worth the time to sort ?
13. How many wood pallets are currently discarded per month ? Is space available to store the 200+ pallets required for pick-up ?
14. What is the total number of dumpsters that are currently used by company A and a neighbor company ? If the two for paper shreds are eliminated, and one is converted to corrugated cardboard only, will adequate capacity remain for solid waste ?
15. What size paint cans are currently used ? How are these currently disposed of ? What is the cost? Is the $80/yr. saving estimated based on disposal cost ?

B) *Clarification of Waste Minimization opportunities*

16. What does the company do with waste acrylic and foil materials ?
17. What is the feasibility of a trash/cardboard compactor ?

18. What is the cost of shipping used 55 gallon drums back to vendors and who would pick up the cost ?

19. If not all the rags are contaminated, what is the feasibility of using rolled rags in the office/bathroom ?

20. Is paper an acceptable packing material ? how does the quantity of paper available compare with the quantity of Styrofoam ?

4.2.3 Decision makers guidelines:

In effort to assist managers and other company principals, a non-conclusive series of questions and answers were developed.

A) Paper:

- *Feasibility:*

  1. Is paper a suitable packaging material for all products? For some products?

     Recommendations:

     a) Buy or lease paper shredder.

     b) Test package products with paper shreds (either in-house or with the help of a packaging consultant).

     c) How much paper is being generated by company A and a neighbor company combined? Is that equivalent to the amount of "Popcorn" used for packaging? If not, how much must be used in conjunction with paper shreds?

- *Cost:*

  1. How much does company A pay for "Popcorn" currently? Is that close to the sum of savings generated by paper cutter and disposal cost?

  2. Would the ability of using waste wi$e (a USEPA's voluntarily WM program) logo generate marketing profits to improve the paper usage feasibility?

B) Wood Pallets:

- *Feasibility:*

1. Would the supplier pick up their pallets on the return trip? If not, what is the amount of wood pallets generated by company A? Is that quantity equivalent to the minimum required by recyclers? If not, does company A have the space to store the pallets? If not, would company A consider hauling the pallets as short cargo on a truck passing a recycling center (e.g. Truck traveling to I-80 passing by a recycler on Salt Springs Road)?

2. Ask suppliers to offer options such as :

   a) Returnable/recyclable top and bottom cardboard covers instead of pallets.

   b) Returnable boxes and crates instead of pallets.

   c) Returnable metal carts/pallets with wheels to deliver supplies.

3. Use returnable plastic pallets: There is an initial investment to purchase plastic, but the cost may be recovered in money deferred from purchasing, repairing, disposing or recycling wood pallets.

4. Use corrugated cardboard pallets: They are lighter than wood which can result in lower freight costs, and they are often cheaper to buy and recycle. However, check their strength.

- *Cost:*

1. What is the cost (if any) of drop-off at recycler? Is that acceptable?

2. Can disposal cost be reduced if pallets are recycled?

3. Any revenues? Can any revenue be obtained from the pallets?

C) Corrugated Cardboard:

- *Feasibility:*

1. Where possible, eliminate cardboard boxes. Work with suppliers in eliminating secondary packaging (i.e. non-recyclable inner packaging and boxes inside

boxes). Have stackable items shrink wrapped to pallets using recyclable wrapping material and ask for parts in form-fitted containers.

2. Ask suppliers if they would take back flat cardboard boxes.

3. When possible, at the time of ordering large quantities of the same item, request one large box to ship vs. smaller boxes.

4. Request a separate container for recyclable flattened cardboard.

5. Identify cardboard recyclers; are they willing to pick up cardboard, or is delivery required?

- *Cost:*

1. Would the reduction in the amount of cardboard affect favorably the cost of in/out freight, disposal?

2. Would the waste company charge less for recyclable cardboard pick-up?

D) Black Paint:

- *Feasibility:*

1. Do you have a practical space for 55 gallon drum containers in the work area? Would the use of these containers affect the efficiency of your production?

2. Would the reduction in paint variation reduce the cost of purchasing and disposal?

3. Can the 55 gallon drum containers be returned to suppliers? If not, can they be recycled?

- *Cost:*

1. Would the saving in the cost of paint disposal (hazardous waste) enough to offset any inconvenience in production?

2. Any savings in paint cost?

3. Any revenue from recycling?

E) Other Considerations:

1. Can the product design be improved to use fewer parts?
2. Is the equipment well maintained?
3. Are the employees well trained and waste conscientious? Do you have any incentive program?
4. Have you requested a competitive bid from recyclers?
5. Are all metal strapping bands, shavings, and floor sweeping collected for recycler?
6. Do you have an updated flow diagram? Material/energy balance?
7. Did you identify your production/waste streams?
8. Do you have a hazardous waste manifest if required?
9. Do you maintain a good log of production and operator schedules?

4.3 Company B:

Company B deals with medium to heavy gauge metal stamping of standard tank heads and engineered contract stampings mechanical processes with a capacity of 50 to 2,000 tons. Company B generates 95 to 96 T/W of scrap metals. Approximately 1/3 is send to the foundry division, 2/3 which consist of reject & unreusable scraps are sold to a recycling company . However, these are the figures as disclosed by the Company B representative. No backup materials were provided. The monthly makeup of used metals is: 80% hot rolled commercial quality steel, 19% hot rolled commercial quality pickled steel, 0.81% stainless steel, < 0.01 aluminum.

The followings are summery of recycling options:

- Company B can implement a cutting list to minimize scrap metals.
- Metal sheets could be purchased in sizes that would minimize the scrap.

- Wood pallets in good shape could be returned to supplier on return trips. Unreusable ones could be picked up by recycler; provided that cardboard, papers are also recycled.
- Pallets, made of a combination of recycled plastic and chipped wood, could be used vs wood.
- BFI is willing to pickup spent sorbants, the supplier could recycle through chemical/ physical process, or it could be sold as a fuel burning source (if it doesn't pollute the air).
- If the wood recycler is not far off the truck routing to Cleveland (i.e. Salt Spring road). The truck can deliver the pallets at minimal cost of transportation.
- A 20 cubic yards dumbster could be provided by BFI/ Waste management, at a reduced cost, for cardboard and papers.
- Different container could be placed in the shop for waste segregation.
- Recycling boxes could be strategically placed through out the plant for recycables (i.e. Aluminum cans) .
- Landrable rags could be used instead of paper rags in bathrooms, shop, kitchen.
- Implementing a corporate policy that will encourage & reward employees for recycling (9).

4.3.1 YSU-TDC Findings:

A YSU-TDC audit team conducted an in-plant audit on February 14, 1995. On February 28, 1995, the team performed a more comprehensive waste stream components study. It was concluded that 570 Ton per month of scrap are produced and 40 cubic yards of solid waste are compacted into a dumpster in the following composition- 35% cardboard, 5% rags, 60% miscellaneous trash (absorbent, floor sweepings, and vending/ miscellaneous paper). The following are the primary WM opportunities identified:

1. <u>Purchasing of plastic pallets for in plant use</u>: they can be manufactured specifically to fit users needs and hold various amounts of weight.

2. <u>Return of specialty sized pallets to supplier</u>.

3. Purchase of wood grinder: this would save Company B the cost of sorbant materials.

4. Purchase of wood chipper.

5. Recycling of wood pallets: this could be done by having a monthly recycler pick-up that will generate income from reusable pallets, or delivery of wood pallets/scrap FOB recycler. Another possibility combine with paper and cardboard recycling which leads to revenue from paper and cardboard depending on their level of contamination.

6. Recycling of cardboard and paper: A 20 cubic yard bundle of corrugated cardboard could be picked-up at a lower rate then regular trash. Dumpsters could be provided at no charge to Company B.

7. Spent sorbants recycling: by returning to supplier or by selling as fuel burning source.

8. Recycling of aluminum cans.

9. Purchasing of specialty metal decoiler.

10. Adaptation of steel decoiler to handle other materials.

11. Training employees to recognize WM opportunities.

12. Use of launderable industrial rags (9).

4.3.2 Questions and additional information from interview:

On April 24, 1995 a memo was sent to YSU-TDC requesting clarifications of several issues related to WM at Company B:

a) *Clarification of Waste Audit results & current operation*

1. What is the total weight of the scrap metals? (95 to 96.7 Tons per week)? minimal
2. Why only 1/3 of the scrap is send to the foundry division and the 2/3 is not?
3. What is the market rate paid by A recycling company ? Could other company pay more & pick up more frequently?

4. If wood pallets are *"USABLE"*, why were they counted as the 3rd component of dumpster waste?
5. Is it feasible to grind unusable pallets? Would it be cheaper if the recycler would handle these pallets?
6. Does the company use fabric towel roles in bathrooms/food area?
7. The listed composition of waste materials adds up to 99.21%. What the 0.79% is? Stainless steel.
8. Are there any other forms to purchase hot rolled steel & other materials?
9. Does the company implement a "Cutting List"?
10. What is done with the metal strapping?
11. The general process flow diagram, suggests that the metal scrap is from the sheet metal only. Is that the case?
12. As an environmentally concerned company, does Company B have any primary treatment to its wastewater?

b) *Clarification of Waste Minimization opportunities*

13. What is the feasibility of using recycled plastic pallets (made with recycled plastic & chipped wood)?
14. Is the stainless steel supplier willing to pick-up their empty pallets on their return trip at no cost to Company B? Yes.
15. What is the bottom line cost to purchase, operate & maintain a wood grinder/chipper? Does it produce enough to be used as a general sorbant? Would the benefit reduction in sorbant cost exceed the total expense? What is the effect on particulate air pollution?
16. What is Company B's cost of transporting unusable wood pallets to a wood grinding facility? Where would Company B store the material meanwhile? There is a facility in Cleveland, where Company B pick up the majority of its materials.
17. Who picks up the cost of transporting spent sorbants? BFI (possible Hazardous material). Would the supplier of sorbants be willing to do that on the return trip? Yes.
18. Is the concession area shared with other divisions?
19. What is the feasibility of purchasing a Steel Decoiler/ Leveler/ Specialty metal cutter? under study.

4.3.3 Decision makers guidelines:

In an effort to assist managers and other company principals, the following series of questions and answers were developed.

A) Metal Strapping:

- *Feasibility:*

1. Is it feasible to reuse the metal strapping at any of the company divisions? If not, could they be sold to recyclers at a market rate?

- *Cost:*

2. Any cost/revenues from shipping the metal strapping?

B) Wood Pallets/Blocking:

- *Feasibility:*

1. Would the supplier pick up their pallets/blocking on the return trip? If not, what is the amount of wood pallets/blocking generated by Company B? Is that quantity equivalent to the minimum required by recyclers? If not, does Company B have the space to store the pallets/blocking? If not, would Company B consider hauling the pallets/ blocking as short cargo to a recycler (e.g. Truck traveling to I-80 passing by a recycler on Salt Springs Road)?

2. Ask suppliers to offer options such as :

   a) Returnable/recyclable top and bottom cardboard covers instead of pallets.

   b) Returnable boxes and crates instead of pallets.

   c) Returnable metal carts/pallets with wheels to deliver supplies.

3. Use returnable plastic pallets: There is an initial investment to purchase plastic, but the cost may be recovered in money deferred from purchasing, repairing, disposing or recycling wood pallets. Check their strength first.

4. Use corrugated cardboard pallets: They are lighter than wood which can result in lower freight costs, and they are often cheaper to buy and recycle. Check their strength first.

5. Is space available for wood grinder/chipper?

6. Are wood chips produced by grinder, a suitable sorbant?

7. Is it possible to work with other companies to purchase a wood grinder? Required if the cost of grinder is to high.

- *Cost:*

1. Would the savings in sorbant cost offset the capital and operational cost of wood grinder/chipper?

2. Can the initial cost of plastic pallets be offset by the saving in disposal costs? If not, would the difference be acceptable?

3. Any revenues from the discarded pallets/blocking?

4. What is the price that LAS Recycling is willing to pay for the papers and cardboard when they pick up the pallets/blocking at no cost to Company B? Is this the most feasible way to handle three waste streams?

C) Corrugated Cardboard and Paper:

- *Feasibility:*

1. Where possible, eliminate cardboard boxes. Work with suppliers in eliminating secondary packaging (i.e. non-recyclable inner packaging and boxes inside boxes). Have stackable items shrink wrapped to pallets using recyclable wrapping material and ask for parts in form-fitted containers.

2. Ask suppliers if they would take back flat cardboard boxes.

3. When possible, at the time of ordering large quantities of the same item, request one large box to ship vs. smaller boxes.

4. Check with BFI and Waste Management for the most feasible way to handle these types of waste?

5. Solicit a bid from all the possible sources for the most feasible way to handle the combination of waste (wood, cardboard, paper, and sorbant).

- *Cost:*

  1. Would the reduction in the amount of cardboard effect favorably the cost of in/out freight, disposal?

  2. Would the waste company charge less for recyclable cardboard pick-up?

  3. Would the ability of using waste wi$e logo generate marketing profits to improve the paper usage feasibility?

D) Sorbants:

- *Feasibility:*

  1. Can the sorbant be filtered in-house for reuse at any division of the company? If not, can it be recycled at any facility for revenue?

  2. Would the supplier pick-up the spent sorbant at no cost to Company B?

- *Cost:*

  3. Any revenues from selling spent sorbant to recycler?

  4. How much saving can be produced by reusing clarified sorbant? Would that offset the cost of filtering spent sorbant?

4.4 COMPANY C:

Company C is a captive foundry producing iron for the hydraulic machining market. It generates approximately 230 Tons of sand per month; which is handled by Waste Management for landfilling. Company C currently reuses & recycle an unknown quantity of various types of scrap metals including large tramp. Small tramp is disposed of with foundry sand (approximately 10% of total spent sand) (9).

4.4.1 YSU-TDC Findings:

The major waste reduction opportunities affording cost savings to Company C were found to be the beneficial reuse of the spent foundry sand, recycling of useable wood pallets, and recycling of mixed office paper, cardboard, plastic, and aluminum cans. The most advantageous approach to this would be implementing a combination of options. Spent sand could be sold to a construction related industry, handled in cooperation with other companies using a prototype repository to improve its quality, or Company B could keep other wastes from contaminating the spend sand. Pallets in good shape could be returned to supplier. Unusable pallets could be handled with the help of a grinder/chipper or it could be picked up by a local recycler, free of charge, if Company B implement a paper & cardboard recycling program. Company B will receive credit for the recycled paper & cardboard. Aluminum cans can be recycled, and Company B would receive $0.50 per Lb. (current rate).

By keeping other waste (tramp and other materials >1 inch in size) separate from the spent foundry sand, the opportunities for reuse could be improved. This would offer a substantial cost savings, possibly half of the current spent sand disposal cost (9).

4.4.2 Questions and additional information from interview:

On April 18, 1995 a memo was sent to YSU-TDC requesting clarifications of several issues related to WM at Company B:

A) ***Clarification of Waste Audit Results & Current Operations*****:**

1. Can the spent sand be sold to builders without major modifications?
2. What is the current charge per container by Waste Management?

3. What type of casting is done?
4. Why is the quantity of scrap metals used undetermined?
5. What is the feasibility of using fine grating under the S-3 conveyor? (Less then 10%)
6. Could the quantity of 'large tramps' could be approximated by taking the difference between the input & output?
7. If less then 10% of sand is contaminated by tramp, how would it save 50% of the cost? By separating these wastes?
8. Are the pallets wood or metal? If wood, why would only a steel manufacturer be interested in purchase?
9. Is the waste generation given from *ALL* divisions, or only the casting?
10. Can the large tramp be re-melted to be used in conjunction with new metals for casting?
11. Why WM's process modification was not suggested?
12. What is the % of waste sand *vs.* new sand used in the casting process?

B) *Clarification of Waste Minimization Opportunities:*

13. How was the 50% saving by offering sand to a construction industry determined?
14. What is the cost of moving the sand to the prototype repository?
15. Who is going to take charge of the repository? Is this going to be some independent company with stocks owned by contributing companies?
16. Investigate the benefits of using 2 sieves in series to trap unwanted tramps?
17. Why not pick up ALL wood pallets when delivering incoming materials? this will eliminate the cost of handling wood pallets.
18. What is the cost of 8' tub chipper? Are there enough unusable pallets to justify the purchase?
19. Does the company want to get involved with selling chipped wood?
20. Why the local recycler is not asked to handle the wood if they are willing to do that for free.

4.4.3 Decision makers guidelines:

In effort to assist managers and other company principal, a non-conclusive series of questions and answers were developed in a flowchart form.

A) Spent Sand:

- *Feasibility:*

1. Check to find out if there is any builder interested in picking up the spent sand for use in construction.
2. If a fine grating is placed on top of a magnetically charged trench, what is the feasibility of collecting all the iron tramp from the spent sand, and therefore, purifying both the sand and metal?
3. Can the core butts and tramp metal be separated from the spent sand in the sand room dumpster?
4. Solicit bids from all the possible sources for the most feasible way to handle the combination of wastes.

- *Cost:*

5. Would the saving in disposal cost offset the cost of improving the quality of spent sand?
6. What revenues could be obtained from selling the spent sand in various purity stages?

B) Paper and Corrugated Cardboard:

1. *Feasibility:* Where possible, eliminate cardboard boxes. Work with suppliers in eliminating secondary packaging (i.e. Non-recyclable inner packaging and boxes inside boxes). Have stackable items shrink wrapped to pallets using recyclable wrapping material and ask for parts in form-fitted containers.
2. Ask suppliers if they would take back flat cardboard boxes.
3. When possible, at the time of ordering large quantities of the same item, request one large box to ship vs. smaller boxes.

4. Check with BFI and Waste Management for the most feasible way to handle these types of waste?

- *Cost:*

5. Would the reduction in the amount of cardboard affect favorably the cost of in/out freight, disposal?

6. Would the waste company charge less for recyclable cardboard pick-up?

7. Would the ability of using waste wi$e logo generate marketing profits to improve the paper usage feasibility?

C) Wood Pallets:

- *Feasibility:*

1. Would the supplier pick up their pallets on the return trip? If not, what is the amount of wood pallets generated by Company C ? Is that quantity equivalent to the minimum required by recyclers? If not, does Company C have the space to store the pallets? If not, would Company C consider hauling the pallets as short cargo to a recycler (e.g. Truck traveling to I-80 passing by a recycler on its way)?

2. Ask suppliers to offer options such as :

   a) Returnable/recyclable top and bottom cardboard covers instead of pallets.

   b) Returnable boxes and crates instead of pallets.

   c) Returnable metal carts/pallets with wheels to deliver supplies.

3. Use returnable plastic pallets: There is an initial investment to purchase plastic, but the cost may be recovered in money deferred from purchasing, repairing, disposing or recycling wood pallets. Test the strength first.
4. Use corrugated cardboard pallets: They are lighter than wood which can result in lower freight costs, and they are often cheaper to buy and recycle. Test the strength first.

5. Is space available for a wood grinder/chipper?

6. Is it possible to work with other companies, if required, to purchase a wood grinder?

- *Cost:*

7. Can the initial cost of plastic pallets be offset by the saving in disposal costs? If not, would the difference be acceptable?

8. Any revenues from the discarded pallets?

9. What is price that LAS Recycling is willing to pay for the papers and cardboard when they pick up the pallets at no cost to Company C? Is this the most feasible way to handle three waste streams?

4.5 COMPANY D:

This company is also located in northeast Ohio. It employs the total of 53 employees. Among these, 35 are on the paint line. It receives aluminum alloy products from various factories to clean, paint and package the items according to the customers preference. Company D produce 100 gallons of paint overspray that need to be recycled. However, Company D currently recycle 75% of its overall waste (9).

4.5.1 YSU-TDC Findings:

Company D has a current waste reduction system that is cost saving, and noteworthy. Company D currently returns to the supplier several types of scrap metals generated as an outcome of the painting processes. Scrap metal not considered reusable, such as steel bands and drums, are sold as scrap to the A recycling company. Company D make an efforts in bailing and recycling of corrugated cardboard. Paper materials can also be recycled by a variety of companies in the same fashion as the cardboard recycling. Keeping an inventory of all paint and solvent waste streams and the recycling of 100 gallons per week of the over-spray paint, recovered through tubular system, are major waste reductions methods; a paint blending company will decide if the over-spray can be reusable.

The use of launderable industrial rags, corrugated cardboard and waste dumpsters, recycling of wood pallets, and plastic sheeting should be seriously considered. Also, reducing the velocity of the wash cycles, order coordination, and the use of a paint line hook should reduce the amount of wastes (9).

4.5.2 Questions and additional information from interview:

On April 27, 1995 a memo was sent to YSU-TDC requesting clarifications of several issues related to WM at Company D:

A) *Clarification of Waste Audit Results & Current Operation:*

1. Is the curent recycler the best buyer for scrap?
2. Are the chemicals used for paint preparation recyclable? (currently being looked at)
3. What type of paint is being used? (oil based)
4. What type of in-house treatment plant does the company have?
5. What is being done with waste solvent? (recycled)

B) *Clarification of Waste Minimization Opportunities:*

6. Could the plastic trap be effectively welded to prevent chemical seepage?
7. Could the unreusable pallet be picked up by a recycler such as BFI? (most likely)

4.5.3 Decision makers guidelines:

In an effort to assist managers and other company principals, the following series of questions and recommendation were developed.

A) Paint Solvent:

- *Feasibility:*

    1. Ensure that used solvents are well collected through the use well joint plastic sheeting.
    2. Utilize an environmentally friendly solvent to clean pieces.
    3. Keep track of the amount of solvent used, and attempt to reuse it as much as practical.
    4. Evaluate storage practices to minimize loss by evaporation.
    5. Would mechanical cleaning be acceptable?

- *Cost:*

    1. Is it cost efficient to check the plastic trap for leakage?
    2. Any revenue from selling the spent solvent?
    3. What are the current disposal costs for spent solvent?

B) Used Paint:

- *Feasibility:*

    1. What is the quantity of used paint is generated during production? Is this a continuous quantity?
    2. Is it possible to use a better quality paint with better coverage or non-solvent based paint?
    3. Could the overspray be used internally? No, due to contamination.

- *Cost:*

4. Would the income from selling used paint be enough to offset any cost in collecting it?

5. Would using other type of paint cost more?

C) Wood Pallets:

- *Feasibility:*

1. Would the supplier pick up their pallets on the return trip? If not, what is the amount of wood pallets generated by Company D? Is that quantity equivalent to the minimum required by recyclers? If not, does Company D have the space to store the pallets? If not, would Company D consider hauling the pallets as short cargo on a truck passing a recycling center (e.g. truck traveling to I-80 passing by a recycler)?

2. Ask suppliers to offer options such as :

   a) Returnable/recyclable top and bottom cardboard covers instead of pallets.

   b) Returnable boxes and crates instead of pallets.

   c) Returnable metal carts/pallets with wheels to deliver supplies.

3. Use returnable plastic pallets: There is an initial investment to purchase plastic, but the cost may be recovered in money deferred from purchasing, repairing, disposing or recycling wood pallets. Check their strength first.

4. Use corrugated cardboard pallets: They are lighter than wood which can result in lower freight costs, and they are often cheaper to buy and recycle. Check their strength first.

- *Cost:*

5. Can the initial cost of plastic pallets be offset by the saving in disposal costs? If not, would the difference be acceptable?

6. Any revenues from the discarded pallets?

7. What is price that LAS Recycling is willing to pay for the papers and cardboard when they pick up the pallets at no cost to Company D? Is this the most feasible way to handle three waste streams?

D) Paper and Corrugated Cardboard:

- *Feasibility:*

1. Where possible, eliminate cardboard boxes. Work with suppliers in eliminating secondary packaging (i.e. non-recyclable inner packaging and boxes inside boxes). Have stackable items shrink wrapped to pallets using recyclable wrapping material and ask for parts in form-fitted containers.
2. Ask suppliers if they would take back flat cardboard boxes.
3. When possible, at the time of ordering large quantities of the same item, request one large box to ship vs. smaller boxes.
4. Check with BFI and Waste Management for the most feasible way to handle these types of waste?

- *Cost:*

5. Would the reduction in the amount of cardboard affect favorably the cost of in/out freight, disposal?
6. Would the waste company charge less for recyclable cardboard pick-up?
7. Would the ability of using waste wi$e logo generate marketing profits to improve the paper usage feasibility?

4.6 Other WM options:

Americans are used to disposable materials more than any other nation on earth. This is evident in the amount of solid waste generated in comparison to other countries. However, public awareness is having an effect in reducing the amount of solid waste generated. It is not a secret that business owners are always interested in the bottom line-cost. Therefore, it is crucial to convince them of the benefits of WM and recycling. The participation in the voluntary Waste Wi$e (10) and Industrial Waste Exchange programs should boost the public image of a company, reduce its environmental torts, and provide some revenues.

A waste exchange is a specialized service which promotes and expedites the recycling of wastes by providing a network for linking wastes (municipal or industrial) with those who may recycle them. A waste exchange is comparable to a specialized classified advertising system where a third party (the waste exchange) maintains confidentiality of the parties listing accessible waste or wanting to use recyclable material. users for these materials are located that might not be located otherwise. Many waste generators have difficulty finding recycling opportunities due to lack of widely available knowledge about those who can do this recycling. Waste exchanges provide a source of information not readily available otherwise, typically reaching thousand of specialists in waste management.

Businesses with 500 employees or less may be eligible to participate in OEPA's Pollution Prevention loan program. This is a low interest capital improvement loans for the construction or purchase of equipment to complete pollution prevention activities.

CHAPTER V
CONCLUSIONS

The best way to solve a problem is to prevent it from happening in the first place. The growing incidence of environmental torts and regulations have prompted officials at all levels of government to focus on the waste minimization (WM) and recycling of both solid and hazardous wastes. For example, USEPA contracted Franklin Associates of Kansas to conduct a comprehensive WM study. They came up with several formulas to estimate WM for commercial and domestic sectors of society. They also, made several industrial recommendations for solid waste management and suggested some formulas for that purpose. Mahoning County Solid Waste Management District (**MCSWMD)** adopted these formulas for the residential and commercial sectors, and decided to conduct a survey and follow-up study to get a more detailed picture of industrial solid waste generation and management. They retained YSU-TDC to conduct free waste audits for the industries within the district. YSU-TDC conducted and is conducting waste audits for several companies. Waste audit reports for three different industries - Company A, Company B, Company C and Company D - were selected for further investigation in this project.

After studying each report, a summary of waste management and WM opportunities was developed, and a memo with several questions for YSU-TDC was generated. Then a meeting was conducted to attempt to get answers for as many questions as possible. Next, research on the type of industry and the latest technology in WM was conducted. Upon gathering the information, a final list of questions and guidelines was made. The goal was to provide additional informations and suggestions that could be used by industrial decision makers in evaluating the WM actions identified by YSU-TDC.

The bulk of WM opportunities consisted of corrugated cardboard, paper, wooden pallets, and paint products. The main WM opportunity for a foundry company was spent foundry sand. Although each company needed its own set of recommendations, there were several common WM opportunities among all of the companies.

In general, the best ways for a company to handle its solid waste is to establish a clear environmental policy, provide incentives for employees to participate, communicate with suppliers, and participate in a waste exchange program. The material covered by this work should be beneficial to the industrial WM decision makers. However, contacting OEPA and the MCSWMD for more detailed help may also be required.

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