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Hazardous Waste Reduction Program of Oregon

Guidelines for Waste Reduction and Recycling

Metal Finishing

Electroplating

Printed Circuit Board Manufacturing

a program of
The Department of Environmental Quality
July 1989

GUIDELINES FOR WASTE REDUCTION AND RECYCLING

METAL FINISHING

ELECTROPLATING

PRINTED CIRCUIT BOARD MANUFACTURING

Prepared by the

HAZARDOUS WASTE REDUCTION PROGRAM
OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY

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OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY
HAZARDOUS WASTE REDUCTION PROGRAM

These guidelines were prepared by the Oregon Department of Environmental Quality's Hazardous Waste Reduction Program. The program was established to provide technical assistance to businesses and industries to reduce the amount of hazardous waste that they generate. Reducing the amount of waste generated helps to control costs and protect the environment.

The DEQ Hazardous Waste Reduction Program works with facilities of all sizes to come up with solutions to the problems associated with the generation, storage, treatment, and disposal of hazardous waste. The program can provide technical information on waste reduction and recycling methods for your business. In addition, the program can provide on-site assistance to identify and implement waste reduction opportunities in your operations.

The program also maintains a technical library containing information on waste reduction and recycling for a wide range of industries. Publications on specific waste reduction methods for electroplating, metal finishing, and printed circuit board manufacturing operations, such as those listed in the references are available. Additional background information and worksheets for conducting a waste reduction assessment are also available.

To obtain information, assistance, or publications on waste reduction or recycling, please contact:

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CHAPTER 1

INTRODUCTION

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There are several good waste reduction and recycling opportunities available for metal finishing, metal fabricating, electroplating, and printed circuit board manufacturing operations. This manual will help you identify methods that can be used in these operations to reduce the amount of waste generated and at the same time help you to achieve other important objectives such as increased profits, productivity, efficiency, and product quality.

WHY SHOULD YOU BE INTERESTED IN WASTE REDUCTION?

Many businesses are finding that waste management is becoming increasingly more burdensome in terms of time, resources, and costs. Of particular concern to these businesses are such issues as:

- strict limits for discharging process wastewaters to the sewer
- costs of wastewater treatment to meet those limits
- regulatory requirements for hazardous waste management
- costs of managing and disposing of hazardous wastes
- liabilities associated with the management of hazardous waste
- land disposal restrictions of certain hazardous wastes

Waste reduction and recycling can help you address these problems and reduce the burden of waste management on your business. Waste reduction is a means of generating less waste in your operations thereby reducing your company's efforts and resources required for waste management.

WHAT DOES WASTE REDUCTION AND RECYCLING MEAN?

Waste Reduction: Waste reduction is any activity that reduces or eliminates the generation of hazardous waste at the source, usually within a production process. These source reduction methods include such activities as good housekeeping practices, raw material substitutions, equipment modifications, production process changes and waste segregation.

Waste Recycling: Waste recycling is the recovery or reuse of what would otherwise be a waste material. Waste recycling activities include the direct use or reuse of a waste material in a process or the reclamation or recovery of a valuable material from a waste. These activities reduce the amount of a waste that requires disposal.

This manual addresses both waste reduction and recycling activities for metal finishing, metal fabricating, electroplating, and printed circuit board manufacturing operations. These methods generally focus on hazardous wastes that are generated in these operations, however, these methods can also be applied to non-hazardous wastes such as wastewaters, air emissions, and solid wastes.

HOW CAN MY BUSINESS BENEFIT FROM WASTE REDUCTION?

Waste reduction and recycling activities can help you to:

- Reduce costs associated with the treatment and disposal of hazardous wastes.
- Reduce raw material/chemical requirements which lowers operating costs.
- Increase production rates and improve product quality.
- Reduce your liability and risks associated with the management of hazardous wastes.
- Improve your company's public image by taking positive steps toward the community's waste problems.
- Create a safer workplace by reducing exposures to hazardous wastes.
- Reduce the burden of trying to comply with regulatory requirements associated with hazardous waste generation.

WHAT TYPES OF INDUSTRIES CAN IMPLEMENT WASTE REDUCTION METHODS?

Any business that generates hazardous waste in their operations, whether it is a small business or a large corporation, can implement some method of waste reduction. This manual specifically focuses on waste reduction and recycling methods for metal finishing, metal fabricating, electroplating, and printed circuit board manufacturing operations.

Industry Overview

Industries involved in metal fabrication, metal finishing, electroplating, or printed circuit board manufacturing utilize a wide range of production processes and operations. These processes include:

- surface preparation/cleaning
- paint stripping
- degreasing
- pickling
- bright dipping and chemical polishing
- electroplating
- electroless plating
- anodizing
- coatings (chromating, phosphating, metal coloring, passivating)
- etching and chemical milling
- painting
- heat treating
- fabrication
- forging
- machining (cutting, grinding, welding, polishing, buffing)

Waste Types Generated by These Industries

These operations can generate potentially hazardous wastes listed below. The classification of a particular waste as hazardous depends upon its specific characteristics and components.

- spent acid or alkaline cleaning solutions
- spent solvents
- spent process baths: plating, etching, pickling baths
- sludges from process baths
- process rinsewaters
- wastewater treatment sludges
- paint residues and sludges
- still bottoms from solvent distillation systems
- spent metal working fluids (coolants, hydraulic fluids, lubricating oils, cutting oils, and quenching oils)

HOW TO USE THIS GUIDANCE MANUAL

Chapter 2 of this guidance manual describes detailed waste reduction methods that can be used to reduce or eliminate the generation of wastes from industrial processes. General waste reduction methods, that can be applied to a wide range of industrial processes, are described, as well as process-specific waste reduction methods for electroplating, metal finishing, and printed circuit board manufacturing operations. Chapter 2 also provides a description of the chemical and metal recovery processes including evaporation, reverse osmosis, ion exchange, electrodialysis, ultrafiltration, and electrolytic recovery.

Chapter 3 describes the procedure for conducting waste reduction assessments. The assessment is a useful tool for identifying and evaluating waste reduction opportunities within a facility's operations.

CHAPTER 2

WASTE REDUCTION AND RECYCLING METHODS

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GENERAL WASTE REDUCTION METHODS

Waste reduction and recycling methods are site- and process-specific, although a number of general approaches and techniques have been used successfully across the country to reduce many types of industrial waste. These techniques range from low or no cost methods to major equipment modifications requiring large capital investments. These techniques can have an application across a range of industries and manufacturing processes, and can apply to hazardous as well as non-hazardous wastes. These general methods include:

- Process and Equipment Modifications
- Input Material Changes
- Improved Operating and Housekeeping Practices
- Recycling

Process and Equipment Modifications

- Redesigning or replacing equipment in order generate less waste.
- Changing the production process to use less raw materials and/or generate less waste.
- Use of automation which helps to limit inadvertent releases and off-spec product generation.
- Changes in operating conditions, such as flowrates, temperature, pressures, residence times.
- Implementing energy and water conservation programs.

Input Material Changes

- Material substitution or replacing a hazardous substance used in a production process with a non-hazardous or less hazardous substance. Examples include replacing a solvent cleaner with an alkaline cleaner.
- Material purification involves the purification of input or feed materials in order to avoid the introduction of inerts or impurities into the production process. When impurities are introduced, the production process must

eventually be purged in order to prevent undesirable accumulation of the contaminants, thus generating a waste. An example of this method is the use of deionized water for process baths and rinsewater in plating operations.

Improved Operating and Housekeeping Practices

- Improved material tracking and inventory practices can reduce the waste resulting from overstocking and disposal of materials with an expired shelf-life. Examples of these methods include:

    - purchasing and using raw materials only as needed.
    - keeping inventories of hazardous substances for each storage area in the plant.
    - monitoring the quantities of waste resulting from expired stock.
    - maintaining Material Safety Data Sheets (MSDSs) for all materials in use.
    - labelling all containers to indicate the name and type of substance, stock number, health hazards, suggestions for handling, and first aid information.

- Improved material usage, handling, and storage can reduce loss of input materials due to mishandling and improper storage. These methods include:

    - standardization of materials or using the minimum number of material types in your operations. This increases the potential for recycling and reduces the amount of waste requiring disposal.
    - improved operation and maintenance of container and drum storage areas. Good operating practices include:

        * providing adequate aisle spacing to facilitate container transfer and easy access for inspections.
        * properly labelling containers with material identification and health and safety hazards.
        * stacking containers according to manufacturers' instructions to avoid

damaging the containers from improper weight distribution.

* segregating different hazardous substances to prevent cross-contamination and mixing of incompatible materials, and to facilitate inventory control.

* storing containers on pallets or similar device to prevent corrosion of the containers which can result when containers come in contact with moisture on the floor.

* constructing secondary containment structures, such as curbs, around storage areas.

- Improved scheduling of batch production runs to reduce the frequency of equipment and tank cleanings can result in less waste being generated.

- Recordkeeping and documentation of operational procedures promotes the consistency of these operations, thereby reducing the likelihood of producing unacceptable products which must be discarded, and helps to identify practices that need to be improved. An operating manual will assist the operators in monitoring waste generation and identifying unplanned waste releases, and assist in responding to equipment failures.

  Recordkeeping should include the following items:

  - documentation of process procedures, control parameters, operator responsibility, and hazards in a manual.

  - waste generation, waste handling and disposal costs.

  - unplanned waste releases such as equipment failures or spills and leaks, and costs of cleanup.

  - MSDSs.

- Preventive maintenance improves the efficiency and longevity of equipment, reduces slow-downs or shutdowns from equipment failures, and reduces the likelihood of producing rejected, off-specification products. Preventive maintenance should consist of regular inspections and cleaning of equipment including lubrication, testing, measuring, and replacement of worn or broken parts.

- Spill and leak prevention includes operational procedures and precautionary modifications to equipment and containment areas to minimize leaks and spills. These measures include:

  - installing and periodically testing overflow alarms on storage, process, and treatment tanks.

  - using tanks and containers according to manufacturer instructions and only for their intended purpose.

  - maintaining integrity of tanks and containers.

  - implementing controlled and supervised loading, unloading, and transfer of all hazardous substances.

  - constructing secondary containment structures around tanks or storage areas containing hazardous substances.

  - developing spill prevention plans.

- Waste segregation promotes recycling and recovery of waste streams and improves the treatability of a waste. Waste types should be segregated as follows:

  - hazardous from non-hazardous wastes (Note: mixing a hazardous waste with a non-hazardous waste generally results in the entire mixture becoming a hazardous waste, which must be managed and disposed as such).

  - liquids from solids.

  - by hazardous constituent, such as chlorinated solvents from non-chlorinated solvents.

  - waste streams containing recoverable metals from waste streams containing chelating agents.

- Employee education and training is an important element of any waste reduction and management program. Employees directly involved with processes and activities that generate wastes should have an understanding of why and how wastes are generated, how they are managed, and costs and liabilities incurred by your company in generating hazardous wastes.

Employee training should consist of:

- health and safety aspects of all hazardous substances being handled.
- proper operation of process equipment and waste recycling and treatment facilities.
- procedures for handling leaks and spills.

- <u>Cost accounting practices</u> include programs to allocate waste treatment and disposal costs directly to the departments or groups that generate the waste, rather than charging these costs to general company overhead accounts.

<u>Recycling</u>

- Direct use and reuse involves the return of waste material either to the originating process as a substitute for an input material or to another process.
- Reclamation or recovery of a valuable material from a hazardous waste.

WASTE REDUCTION AND RECYCLING APPLICATIONS

Several waste reduction and recycling methods which can be applied to metal fabricating, metal finishing, electroplating, and printed circuit board manufacturing operations are summarized below. When identifying and evaluating waste reduction options for your operations, the emphasis should be placed first on the simple, low or no cost material handling and process changes. After these alternatives have been considered, then the more expensive equipment modification and waste recovery options should be evaluated. Waste reduction and recycling methods include:

- Improved Operations and Housekeeping Practices
- Drag-Out Reduction
- Rinsewater Modifications
- Material/Chemical Substitutions
- Plating Bath Maintenance
- Chemical Recovery Processes
- Metal Recovery Processes
- Sludge Management
- Solvent Management

IMPROVED OPERATIONS AND HOUSEKEEPING PRACTICES

The following practices are easy to implement and require little or no capital investment:

- Repair all leaking tanks, pumps, valves, etc.
- Inspect tank and tank liners on a regular basis to prevent failures that may result in bath dumps.
- Inspect steam coils and heat exchangers on a regular basis to prevent accidental contamination of steam condensate and cooling water or leakage of condensate and cooling water into the plating bath.
- Install high-level alarms on all plating and rinse tanks to avoid accidental bath overflows.
- Maintain plating racks and anodes to prevent contamination of baths. Remove racks and anodes from baths when not in use.
- Minimize the volume of water used during cleanup operations.
- Properly train plating personnel so that they understand the importance of minimizing bath contamination and waste generation, and preventing spills.
- Properly clean and rinse parts prior to plating to minimize contamination of the plating bath. Areas that are not to be plated should be masked or stopped off with tape or wax to limit corrosion from these areas. Parts should be removed from the bath when not being plated.

DRAG-OUT REDUCTION

Drag-out refers to the plating solution that adheres to the parts after they are taken out of the plating bath and is carried-over into the rinsewater. Drag-out represents the largest volume source of wastewater in electroplating operations. Minimizing drag-out will reduce the amount of contaminants entering the next process bath or rinsewater, thus reducing the volume of waste that must be treated and disposed.

Several techniques have been developed to control drag-out. These drag-out reduction methods are inexpensive to implement and are repaid through savings in plating chemicals. These methods include:

- Modifying properties of the plating bath to improve drainage of the plating solutions back into the plating baths or reduce the concentration of dissolved metals in the drag-out. These methods include:
  - Decreasing bath viscosity: by reducing the chemical concentration of the bath or by increasing the bath temperature.
  - Decreasing bath surface tension: by adding non-ionic wetting agents or increasing bath temperature.
- Lowering the withdrawal rate of parts from a bath. This method can reduce the thickness of a drag-out layer because of surface tension effects.
- Increasing the drain time over the plating tank.
- Installing drain boards, drip bars, and drip tanks to capture the drag-out. The collected drag-out can be fully or partially returned to the plating bath to make up for evaporative losses. These devices save chemicals, reduce rinse requirements, and prevent unnecessary floor wettings.
- Proper racking: Carefully rack and remove parts so as to minimize entrapment of bath materials on surfaces and in cavities:
  - parts should be racked with major surfaces vertical.
  - parts should not be racked directly over one another.
  - parts should be oriented so that the smallest surface area of the piece leaves the bath surface last.
- Designing parts to promote drainage, such as with no cups or shelves.
- Designing plating racks with a minimum surface area, minimum horizontal surfaces, no pockets, and an effective orientation to promote drainage.
- Using air knives with oil-free compressed air to knock plating films off parts and back into the plating tanks.
- Using fog and spray rinses, parts can be spray rinsed with deionized water over the plating tanks. This method is used when tank evaporation rates are

sufficient to accommodate the added volume of spray water.

- In rack plating: Provide drain bars over the plating tank from which the rack can be hung to drain for a brief period.

- In barrel plating: Rotate the barrel over the plating tank to remove excess plating solution.

RINSEWATER MODIFICATIONS

Methods are available to improve rinse efficiency and reduce the amount of rinsewater generated. These methods include the use of one or more of the following:

- Still rinse or drag-out tank: A still rinse tank can be used prior to the rinse tanks with flowing water. As the concentration of the plating solutions in the still rinse tank builds up over time, the rinsewater can be returned to the bath to make up for evaporation losses.

- Rinse tank mixing: The even distribution of fresh water throughout the rinse tank in addition to aeration can increase the efficiency of water use.

- Water supply control valves: These are inexpensive devices to regulate the feed rate of water at an optimum level.

- Spray rinsing: In this method, when the workpiece is sprayed with water, the process solution films are washed off the parts through use of impact and diffusion forces. This method, which can reduce water usage as much as 75%, is effective on simple workpieces, such as sheets, but has limited application for odd-shaped pieces.

- Fog rinsing: This method uses water and air pressure to produce a fine mist which reduces the concentration of the drag-out film. This method is effective on simple workpieces but has limited application for odd-shaped pieces.

- Cascade rinsewater recycling: In this method, overflow from one rinse tank can be used as the water supply for another compatible rinsing operation.

- Countercurrent rinsing with multiple tanks: In this arrangement, three rinse tanks are operated in series with the water flowing from the tank farthest away from the plating tank toward the tank closest to the plating tank by gravity or pumping. The workpiece is sequentially immersed in each of the three rinse tanks, countercurrent to the rinsewater flow, from the least pure rinse tank to the cleanest rinse tank.

- Countercurrent rinsing can reduce rinse flows by over 95% compared to single overflow rinses.
- Disadvantages with this arrangement include additional space requirements, additional production time requirements, and costs of additional rinse tanks.

MATERIAL/CHEMICAL SUBSTITUTIONS

The incentive for substituting process chemicals containing nonpolluting materials has surfaced in recent years in response to the increasing complexity of pollution control regulations. By eliminating polluting process materials such as hexavalent chromium or cyanide-bearing chemicals, the treatments required to detoxify these wastes are also eliminated. This is desirable particularly for hexavalent chromium and cyanide wastes since they require a special treatment step and equipment to detoxify.

Material and chemical substitutes are now being gradually introduced into the marketplace by chemical manufacturers and suppliers. When evaluating and selecting chemical substitutes for a particular application, a number of factors should be considered, such as:

- Are substitutes available and practical?
- Will substitutes solve one problem but create another?
- Will tighter chemical controls be required of the bath?
- Will product quality and/or production rate be affected?
- Will the change involve any cost increases or decreases?

Some commonly used material and chemical substitutes in electroplating, metal finishing, and printed circuit board manufacturing operations are summarized below:

Chemical Substitutes for Alkaline Cyanide Plating Baths

- In zinc plating, chemical substitutes include:
  - ammonium or potassium chloride baths for complexing zinc.

- acid sulfate, chloride, and fluoroborate baths.

- In cadmium plating, chemical substitutes include:
  - acid baths consisting of cadmium oxide, sulfuric acid, distilled water and anionic compounds.
  - cadmium chloride.
- In copper plating, copper sulfate can be used as a chemical substitute.
- In tin plating, acid tin chloride can be used as a chemical substitute.

Chromium Plating Baths

- Trivalent chromium solutions can be used in place of hexavalent chromium solutions in some situations. This reduces drag-out concentrations of chromium.

Pickling Solution and Bright Dip Alternatives

- Sulfuric acid and hydrogen peroxide can be used as substitutes for chromic acid.

Cleaners

- Trisodium phosphate or ammonia can be used as substitutes for cyanide cleaners.

Copper Etchants

- Sulfuric peroxide can be used as a substitute for persulfate.

PLATING BATH MAINTENANCE

Plating solutions contain valuable metals in high concentrations as well as chemical salts and additives. Over a period of time, contaminants can build up in the plating bath and reduce the effectiveness of the plating operation. For reasons of economics, these plating baths are rarely ever changed out or dumped. Several methods are available to maintain the quality of the plating bath and include:

- Removing impurities from plating baths:
  - Suspended solids can be removed by filtering.

- Nickel baths can be purified by activated carbon adsorption.

- Carbonates in cyanide baths can be removed by chemical precipitation.

- Using deionized water for makeup and as rinsewater.

CHEMICAL RECOVERY PROCESSES

Chemical recovery processes are available to reconcentrate plating solutions from rinsewater for reuse and to purify spent process solutions. These methods are summarized below. When evaluating a recovery process for a particular plating operation, general and site-specific factors must be considered. These factors include the metal being plated, drag-out rates, concentration of metals in the rinsewater, rinsewater flow-rates, space requirements, personnel requirements, energy requirements, and cost and payback period of the recovery system.

Evaporation: In this process, rinsewater is boiled to concentrate the plating solution. Steam from the process is condensed and reused for rinsing. The plating solution is returned to the plating bath. This process can recover 90 to 99% of the dragged-out metals.

Application: Drag-out recovery of rinsewaters from:
- hot chromium baths
- ambient temperature nickel baths
- metal cyanide baths

Use in conjunction with countercurrent rinsing.

Advantages: Simple, reliable, widely applicable process.

Relatively maintenance-free compared with other recovery processes.

Disadvantages: High energy use.

Requires periodic removal of impurities from the recovered plating solutions.

Reverse Osmosis: In this process, water is separated from dissolved metal salts by forcing the water through a semipermeable membrane at high pressures. A concentrated solution containing the plating metals is produced and returned to the plating bath. The purified water is reused for rinsing. This process can recover up to 99% of the dragged-out metals.

Application: Drag-out recovery of rinsewaters from the following plating baths:

- acidic nickel (Watts nickel lines)
- nickel sulfamate
- copper pyrophosphate
- copper sulfate
- nickel fluoroborate
- zinc chloride
- zinc sulfate
- cyanide baths for copper, zinc, and cadmium

For use on lines with heated plating baths where evaporation is high enough to allow the concentrate to be fed directly to the plating bath.

Use in conjunction with still rinse tanks, countercurrent rinsing, or other rinsewater conservation techniques.

Advantages: Produces medium to high concentrations of metal salts for reuse in the plating baths.

Performs efficiently on dilute rinsewaters.

Disadvantages: Nonselective in removing dissolved substances from the solution. Impurities such as organic brighteners, wetting agents, and unwanted metals may be returned to the plating bath along with the recovered metal.

To prevent fouling of the membrane, prefiltering of the rinsewater is required to remove solid particles, oxidizing materials, and oil and grease.

Limited application for solutions with high oxidation potential (chromic acid) or extreme pH (i.e. high pH cyanide baths) due to destruction of membranes.

Ion Exchange: The ion exchange process can be used for removing contaminants from process baths or recovering dissolved metals from rinsewaters. The process can recovery 90 to 95% of the metals in drag-out.

There are two types of ion exchange units, cation and anion. The selection of the type of ion exchange unit to use for a particular application will depend upon the ionic charge of the contaminant to be removed or metal to be recovered.

A cation exchange unit contains a specific type of resin to remove positively charged ions from solution, such as metal cations. The cations removed from the solution are typically replaced by hydrogen ions that are displaced from the resin. The solution that exits the cation exchange unit has a limited potential for reuse as a rinsewater due the presence of the hydrogen ions which make the solution acidic.

After a period of time, the capacity of the resin to remove additional metal cations becomes limited and the resin must be regenerated if it is to be further utilized. Regeneration of the cation exchange unit consists of passing a strong acid, such as sulfuric acid, through resin bed. The solution exiting the cation exchange unit from the regeneration process contains the metal ions, which can be returned to plating bath.

An anion exchange unit contains a type of resin to remove negatively-charged ions from solution, such as chromate and cyanide. Typically with anion exchange units, hydroxide ions are displaced from the resin to replace the anions removed from the solution. The anion exchange units are regenerated with a strong base, such as sodium hydroxide.

Application: Purification of spent process acids.

Recovery of anodizing baths.

Drag-out recovery of rinsewaters from the following plating baths:

- Acid copper
- Acid zinc
- Nickel
- Tin
- Cobalt
- Chromium

Advantages: Can remove all metal ions from a relatively dilute solution.

Low capital and operating costs compared to other recovery processes.

Disadvantages: Not capable of producing a highly concentrated stream for return to the plating baths.

Does not remove organic additives from a wastewater.

Prefiltering of the rinsewater may be required to remove solid particles and oil which can cause fouling of the resin.

Not cost effective when drag-out rates are low.

Equipment is complex, requiring tight operation and maintenance.

Monitoring of the ion exchange unit is required to ensure that the resin capacity is not exceeded.

Resins require periodic regeneration with strong acid or caustic.

Electrodialysis: In this process water is separated from dissolved salts using a network of alternately-spaced anion-permeable and cation-permeable membranes. An electric potential is applied across the membranes to provide the driving force. This process can recover 90 to 95% of the metals in drag-out.

Application: Regeneration of chromic acid etchant.

Drag-out recovery of rinsewaters from the following plating baths:

- nickel
- acid zinc

- zinc cyanide
- chromium
- gold
- silver
- tin

Use in conjunction with a still rinse tank.

Advantages: Achieves higher concentration of metals than reverse osmosis or ion exchange.

Energy efficient.

Can operate continuously without requiring regeneration.

Requires little space.

Disadvantages: Nonselective in removing dissolved substances from the solution. Impurities such as organic brighteners, wetting agents, and unwanted metals may be returned to the plating bath along with the recovered metal.

Membranes are sensitive to extreme pH, flow variations, and suspended solids.

Prefiltering of the rinsewater may be required to remove solid particles and oil which can cause fouling of the resins.

Requires careful operation and periodic maintenance to avoid damage to the membranes.

<u>Ultrafiltration</u>: In this process, a solution is filtered through an extremely fine filter to remove solids, emulsions, and high molecular weight organics.

Application: Regeneration of alkaline cleaners, coolants, or process baths requiring removal of particles and emulsified oils.

Wastewater treatment process for volume reduction of spent coolants, cleaners, and rinsewaters.

Advantages: Efficient for removing suspended solids, emulsified oils, and other high molecular weight organic compounds.

Low capital and operating costs.

Easy to operate and requires little maintenance.

Disadvantages: Limited application for recovery of dissolved metals from rinsewaters.

Requires periodic backwashing to remove captured solids.

METAL RECOVERY PROCESSES

Electrolytic Recovery: This process involves the electrochemical reduction of metal ions to their elemental forms as a powder or foil. A direct current is passed through a metal-bearing solution by means of cathode plate and insoluble anodes. The cathode consists of a stainless steel or carbon fiber plate upon which the recovered metal is deposited. After the coating is sufficiently thick, the metal is peeled off and sent to a refiner or the coated stainless steel cathode is used as an anode in plating baths, serving a source of metals.

Application: Oxidation of cyanide.

Reduction of hexavalent chromium in wastewaters.

Recovery of metals from plating and etching bath drag-out, such as gold, silver, copper, cadmium, zinc, tin, and lead.

Regeneration of ammoniacal and chloride etch solutions during metal recovery.

Use in conjunction with a still rinse tank.

Advantage: Not a labor-intensive operation.

Low energy requirements.

Low energy requirements.

Disadvantages: Limited application for recovery of chromium from solutions.

Monitoring of the solution concentration is required.

SLUDGE MANAGEMENT

Sludges produced in process baths and as a result of wastewater treatment processes are typically hazardous wastes that must be appropriately managed. Frequent management problems with these sludges include the high volumes generated that must be handled and costs for disposal. Some waste management alternatives are available to help alleviate these problems.

Sludge Dewatering

Several mechanical dewatering devices that reduce sludge volumes are commercially available. These devices include:

- Centrifuges
- Filter presses
- Vacuum filters
- Sludge dryers

Treatment Chemical Selection

A wide range of treatment chemicals is available for precipitating dissolved metals out of a solution. Some of these chemicals produce less sludge when compared to other chemicals of comparable removal efficiency. Therefore, the selection of a treatment chemical for a particular application is important for reasons of efficiency and sludge volume production.

Examples of treatment chemicals that produce less sludge include:

- use of caustic soda (NaOH) instead of lime ($Ca(OH)_2$).
- use of polymers instead of ferrous sulfate and alum.

SOLVENT MANAGEMENT

Organic solvents are widely used in metal finishing operations for cleaning, degreasing, and paint stripping. The management and disposal of spent organic solvents are becoming increasingly more difficult and expensive. Some waste reduction and recycling methods for organic solvents are summarized below.

Material Substitution

Alternatives to using solvents include:

- Alkaline cleaners
- High pressure hot water washings
- Steam cleaning
- Mechanical blasting in place of chemical strippers to remove paints and rust. In this method particles, such as plastic beads, sand, or aluminum oxide pellets, are blown with high pressure air or water onto the workpiece. The particles can be recovered and reused.

Recovery and Reuse

Methods for reusing and recovering spent solvents include the following:

- Cascade reuse: This involves using a spent solvent from a precision cleaning operation as a cleaner for another process that does not require a high purity solvent.
- Onsite distillation systems: Solvent distillation systems are commercially available for use in metal finishing applications.
- Offsite recycling: Several waste management services are available for recycling spent solvents either at your facility site or at an offsite location.

CHAPTER 3

WASTE REDUCTION ASSESSMENTS

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A waste reduction assessment is a step-by-step procedure that can be used by a facility's own employees to identify waste reduction and recycling opportunities. The assessment can help you to understand the facility's wastes and processes, identify viable options for reducing wastes, and determine which options are technically and economically feasible to justify implementation in your operations.

The amount of effort required for a waste reduction assessment will depend upon the size and type of your business. Small facilities with only a few processes will obviously require less time and resources for the assessment. Large facilities with many processes may require a team of skilled professionals to conduct a more detailed technical and economic evaluation of waste reduction options.

Considering the wide range of waste reduction and recycling opportunities available for metal finishing and electroplating operations, it is likely that your business can implement waste reduction methods and end up saving money as a result. The following steps will provide you with some general guidance in identifying and implementing waste reduction and recycling practices in your operations. Note that all waste streams should be considered when conducting an assessment, such as hazardous wastes, wastewaters, air emissions, and non-hazardous solid waste. Additional sources of information on waste reduction methods and implementation can be found in the references.

There are several different tasks involved when conducting a waste reduction assessment. These tasks include the following:

- Planning and Organization
- Assessment Phase
- Feasibility Analysis
- Implementation and Evaluation

PLANNING AND ORGANIZATION

Planning and organizing waste reduction assessment activities are essential steps to ensure a program's success. This task is conducted prior to actual assessment phase. Important elements of this task are summarized below.

- Get a commitment and support from management. It is important for the management of a company to support a waste reduction program. The management must be able to provide the time, personnel, financing, and other resources required for developing a waste reduction program.

- Develop a formal policy statement describing the waste reduction program objectives.

- Involve employees in all phases of waste reduction program development.

- Organize a waste reduction assessment team.

  - Get people who know the facility, processes, and operating procedures, and are familiar with your waste management practices, environmental regulations, and waste reduction and recycling techniques.

  - Get people from affected departments or groups, such as production, maintenance, environmental, safety, sales, purchasing, etc. Involve line operators and production supervisors.

  - Appoint a team leader who has a strong technical background and good problem-solving and management skills.

- Set goals to achieve waste reduction.

- Recognize potential barriers and problems that may hinder waste reduction program development.

ASSESSMENT PHASE

This phase involves an evaluation of the facility's operations, waste streams, and waste management practices and the identification and screening of potential waste reduction and recycling options. Important steps of this phase include the following:

1) Collecting Facility Information

One of the first steps of the assessment is to gather background information on production processes, operating procedures, waste streams, and current waste management activities. Collecting data will create a basis by which the assessment team can track the flow and characteristics of the waste streams over time. This will be useful in identifying trends in waste generation and will also be critical in the task of measuring the performance of implemented waste reduction and recycling options later.

The types of data and information that are useful for conducting an assessment are listed below. Note that all of the information listed may not be readily available. Much of this information can be collected when conducting the site inspection. However, as much information as possible should be collected prior to the site inspection so that the assessment team is better prepared.

<u>Production Processes and Operational Procedures</u>:

- production rates
- process descriptions and efficiencies
- condition of process equipment, such as tanks, pumps, pipes, and valves
- sources or potential sources of leaks and spills
- operating procedures
- maintenance procedures and schedules
- operating and maintenance costs
- energy/utility usage and costs

<u>Material Usage, Handling, and Storage</u>:

- material inventory
- raw material usage and accountability (i.e. how much of the raw material is actually used in the process, how much is lost through evaporation or other means, and how much enters a waste stream)
- raw material costs
- material transfer and handling procedures
- storage procedures
- sources of leaks or spills in transfer and storage areas
- condition of pipes, pumps, tanks, valves, and storage/delivery areas

Waste Stream Data:

- activities, processes, or input materials that generate waste streams
- physical and chemical characteristics of the each waste stream
- hazardous classification of each waste stream (i.e. which wastes are hazardous and which are not?)
- frequency of waste stream generation (i.e. continuous or intermittent, such as from periodic cleaning activities or bath dumps)
- rates of generation of each waste stream and any variability in these rates

Waste Management:

- current disposition of each waste stream (i.e. how is it handled, treated, and disposed)
- costs of managing waste streams, including treatment and disposal costs
- operational procedures for waste treatment units
- efficiency of waste treatment units
- quantity and characteristics of all treated wastes, sludges, and residues
- waste stream mixing (are hazardous wastes mixed with non-hazardous wastes or are potentially recyclable wastes mixed with other wastes?)

Waste Reduction:

- current waste reduction and recycling methods being implemented
- effectiveness of those methods

Sources of Background Information

Some sources of information on operations, processes, and waste generating activities, and waste streams include the following:

- process flow diagrams
- material and heat balances for production processes and waste treatment processes
- operating manuals and process descriptions
- equipment lists
- equipment specifications and data sheets
- piping and instrument diagrams
- plot and elevation plans
- sewer diagrams
- equipment layouts and work flow diagrams
- hazardous waste manifests
- emission inventories
- annual hazardous waste reports
- waste analyses
- environmental audit and inspection reports
- permits and permit applications
- wastewater discharge monitoring reports (NPDES or sewer discharges)
- toxic substance release inventories (SARA Title III requirements)
- product composition and batch sheets
- material application diagrams
- material safety data sheets (MSDS)
- product and raw material inventory records
- operator data logs
- production schedules
- departmental cost accounting reports
- company environmental policy statements
- organization charts

In some situations it may be necessary to develop flow diagrams and material or mass balances of the major waste generating operations. These flow diagrams and mass balances help to identify waste sources, concentrations, and rates of generation.

2) Prioritizing Production Processes, Operations, and Waste Streams for Further Assessment

When funds, time, and personnel are limited, it may be necessary to prioritize the processes, activities, or waste streams for further evaluation. The waste reduction assessment should focus on the most important waste problems first and then address the lower priority problems as time, personnel, and budget permit.

Items that should be considered when prioritizing include:

- compliance with current and future regulations
- costs of waste treatment and disposal

- potential environmental and safety liability

- quantity of waste

- hazardous properties of the waste (including toxicity, reactivity, corrosivity, and ignitability)

- safety hazards to employees

- potential for reduction, recycling, or recovery

- potential for removing bottlenecks in production or waste treatment

- potential recovery of valuable by-products

- available budget and expertise for the waste reduction assessment program and projects

3) <u>Site Inspection</u>

The purpose of the site inspection is to verify background information, fill data gaps and resolve questions raised while collecting and reviewing data, identify additional sources of wastes, and collect information on actual operating and waste management practices. The inspection concentrates on understanding how and why wastes are generated.

For each of the selected processes or operations being evaluated, the inspection should follow the process from the point where raw materials enter the process to the point where products and wastes exit.

Some general guidelines for conducting the site inspection include the following:

- Prior to the inspection:

  - make a list of items that require clarification.

  - notify personnel involved within the process or area to be inspected.

- Schedule the inspection to coincide with the particular operation of interest, if the operation is periodic or intermittent in nature (e.g. bath dumping, chemical addition, etc.).

- During the inspection take notes and photograph the areas of interest. This helps to recall details that may be forgotten at a later date.

- Monitor the operation at different times during the shift and during the different shifts, especially if waste generation is highly dependent on human involvement.

- Interview the operators, maintenance personnel, shift supervisors, and foremen in the areas being inspected. Assess the operators' and supervisors' awareness of the waste generation aspects of the operation and familiarity with the impacts their operation may have on other operations.

- Observe housekeeping aspects of the operation. Check for signs of leaks or spills. Assess the overall cleanliness of the site. Note any odors and fumes.

- Evaluate the organizational structure and level of coordination of environmental activities between various departments.

- Evaluate administrative controls, such as cost accounting procedures, material purchasing procedures, and waste collection procedures.

4) Generating Waste Reduction Options

After the data collection and site inspection stages of the assessment, the next step involves identifying possible waste reduction and recycling options. This step requires the expertise of the assessment team members. Much of this knowledge comes from their education and on-the-job training. Other sources of waste reduction and recycling information are listed below:

- Trade associations
- Plant engineers and operators
- Published literature such as technical journals, trade journals, government reports, conference proceedings, and research reports
- DEQ Waste Reduction Program
- Workshops, conferences, and seminars
- Equipment vendors
- Consultants and employees from other facilities

Waste reduction and recycling methods for electroplating, metal finishing, and printed circuit board manufacturing operations were discussed in Chapter 2 of this guidance manual.

5) Screening and Selecting Waste Reduction Options for Further Evaluation

Since detailed evaluation of technical and economic feasibility is usually costly, the proposed waste reduction options should be screened to identify those that deserve further evaluation. The screening procedure serves to eliminate suggested options that appear marginal, impractical, or inferior without a detailed and more costly feasibility study.

When considering options, emphasis should be placed on process changes and other source reduction measures, followed by recycling and reuse. Many source reduction options involve no or low capital costs and can be easily implemented. After these alternatives have been considered, then the more expensive equipment modifications and waste recycling options should be evaluated.

The following criteria should be considered when screening and selecting options:

- existing technology (does the necessary technology exist to develop the option?)
- extent of current use in the industry
- successful performance history
- cost and cost effectiveness
- reduction in the waste's quantity and hazardous characteristics (toxicity, flammability, reactivity, corrosivity)
- reduction of treatment and disposal costs
- reduction in safety hazard
- reduction in liability and insurance costs
- reduction of input material costs
- effect on product quality
- low capital cost
- low operation and maintenance costs

- short implementation period
- ease of implementation
- other benefits

FEASIBILITY ANALYSIS

After identifying potential waste reduction and recycling options, the next step is to conduct a detailed analysis of these options. The analysis of these options includes both a technical and economic evaluation.

Technical Evaluation

The technical evaluation determines whether a proposed waste reduction option will work in a specific application. The following criteria should be considered when conducting a technical evaluation:

- **Will the option work in this application?**
- **How has it worked in similar applications?**
- **Will the option create less waste or just move the waste problem from one form to another?**
- **Is the system safe for workers?**
- Will product quality be maintained?
- **Will the option adversely affect productivity?**
- **Is space available?**
- **Are the new equipment, materials, or procedures compatible with production operating procedures, work flow, and production rates?**
- **Is additional labor required?**
- **Are utilities available or must they be installed?**
- **How long will production be stopped in order to install the system?**
- **Is special expertise required to operate or maintain the new system?**
- **Does the vendor provide acceptable service?**
- **Does the system create other environmental problems?**

For equipment related options:

- Visit facilities that have installed the equipment. These visits can be arranged through equipment vendors and industry contacts.
- Solicit operator's comments and compare to vendor claims.
- Conduct bench-scale or pilot demonstrations. Rental test units for bench-scale experiments may be available from equipment vendors for use.
- Some vendors may install equipment on a trial basis, with acceptance and payment after a prescribed time, if the user is satisfied.

Economic Evaluation

The economic evaluation is conducted using standard measures of profitability, such as payback period, return on investment, and net present value. Most companies have their own methods for evaluating projects for implementation. In conducting an economic evaluation various costs and savings must be considered. Some of these factors are described below.

For the purpose of evaluating a project to reduce waste quantities, some types of costs are more significant and easily quantified. These costs include:

- disposal fees
- transportation costs
- predisposal treatment costs
- raw material costs
- operating and maintenance costs

When conducting the economic evaluation of waste reduction options, these costs should be considered first because they have a greater effect on project economics and involve less effort to estimate reliably. Other elements, such as those listed below, are usually secondary in their direct impact and should be included in fine-tuning the analysis.

Capital Costs:

- site development
- process equipment
- materials
- connections to utilities and services
- new utility and service facilities
- other non-process equipment
- construction/installation

- engineering and consulting services
- permitting costs
- contractor's fees
- training costs
- finance charges

Operating Costs and Savings:

- Reduced waste management costs
  - onsite and offsite treatment, storage, disposal costs
  - state generator fees
  - transportation costs
  - permitting, monitoring, reporting, and recordkeeping costs

- Input material cost savings

- Insurance and liability savings

- Changes in cost associated with product quality (costs for scrap, rework, and quality control inspections)

- Changes in utility costs

- Changes in operating and maintenance costs for labor, burden, and benefits

- Changes in operating and maintenance supplies

- Changes in overhead costs

- Changes in revanues from increased (or decreased) production

- Increased revenues from the sale of by-products

Final Report

Following the assessment and feasibility analyses, a report should be prepared that presents the results of the assessment and the technical and economic evaluations. The report also contains recommendations to implement the feasible options. This report is an important tool for getting a project funded and implemented. All affected groups and departments should be given the chance to review and comment on the report. The report should contain a discussion of the following topics:

- waste reduction options evaluated and results of the evaluation

- recommended options for implementation

- whether the recommended technology or procedure has been established in the industry, with a mention of successful applications

- how the project will be implemented

- required resources, such as money, expertise, personnel, available in-house and those resources that must be brought in from outside

- estimated construction period and production downtime

- expected performance of project

- how the performance of the project can be evaluated after it is implemented

- reduction in environmental and safety liability

IMPLEMENTATION OF WASTE REDUCTION AND RECYCLING OPTIONS

The implementation of selected waste reduction and recycling will generally follow the procedures established by your company for implementing any new procedure, process modifications, or equipment change. The assessment report will help to get management approval and funding for implementation of the selected projects. Steps involved in implementing a waste reduction project include the following:

- preparing a detailed design
- preparing a construction bid package
- selecting construction staff and purchasing materials
- installing new equipment
- training personnel
- starting operation
- monitoring and evaluating performance

Once a project has been implemented and operating, it is important to evaluate its performance. Options that do not perform as expected may require rework or modifications. This evaluation also provides important information for future uses of this option in other applications. Successful projects will show the value of waste reduction to your company and serve to justify the development of other waste reduction projects.

The waste reduction assessment program should be viewed as a continuing program rather than as a one-time effort. As waste reduction and recycling options are implemented, the assessment team should continue looking for new opportunities, assess other waste streams or processes, and consider attractive options that were not pursued earlier.

REFERENCES

Information contained in this guidance document has been derived from the following sources:

Higgins, T. E., CH_2M Hill, Evaluating Hazardous Waste Minimization Programs for Metal Finishing Processes. Presented at the AOI/AEA/DEQ workshop on "Responsible Hazardous Waste Management", Wilsonville, Oregon, March 24, 1987.

Lorton, G. A., and D. A. Hanlon, Jacobs Engineering Group Inc., Waste Minimization Assessments. Presented at the California Aerospace Environmental Association Conference, Long Beach, California, February 17, 1988.

New York State Department of Environmental Conservation, Draft New York State Hazardous Waste Reduction Guidance Manual, November 1988.

U.S. Environmental Protection Agency, Summary Report, Control and Treatment Technology for the Metal Finishing Industry, In-Plant Changes, Industrial Environmental Research Lab, Cincinnati, Ohio, EPA/625/8-82-008, January 1982.

U.S. Environmental Protection Agency, Meeting Hazardous Waste Requirements for Metal Finishers, Seminar Publication, Office of Research and Development, Cincinnati, Ohio, EPA/625/4-87/018, September 1987.

U.S. Environmental Protection Agency, Waste Minimization: Environmental Quality with Economic Benefits, Office of Solid Waste and Emergency Response, Washington, D.C., EPA/530-SW-87-026, October 1987.

U.S. Environmental Protection Agency, The EPA Manual for Waste Minimization Opportunity Assessments, Hazardous Waste Engineering Research Laboratory, Cincinnati, Ohio, EPA/600/2-88/025, April 1988.

For additional references on waste reduction and recycling, refer to DEQ's Bibliography of Hazardous Waste Reduction Publications.