United States
Environmental Protection
Agency

Research and Development

Hazardous Waste Engineering
Research Laboratory
Cincinnati OH 45268

EPA/600/S2-87/056 Jan 1988

Project Summary

Waste Minimization Audit Report: Case Studies of Minimization of Cyanide Waste from Electroplating Operations

To promote waste minimization activities in accordance with the national policy objectives established under the 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act of 1976 (RCRA), the Hazardous Waste Engineering Research Laboratory (HWERL) of the USEPA Office of Research and Development has undertaken a project to develop and test a waste minimization (WM) audit procedure.

As part of this project, a total of 6 WM audits were carried out in four separate facilities. This report presents the results of the on-site WM audits performed at two electroplating facilities that generate cyanide-bearing wastes. The report also describes the WM audit procedure as it has developed from the initial (pre-project) sequence of steps, to the modified (post-project) sequence that reflects the experience gained during this HWERL project.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

To promote waste minimization activities in accordance with the national policy objectives established under the 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act of 1976 (RCRA), the Hazardous Waste Engineering Research Laboratory (HWERL) of the USEPA Office of Research and Development has undertaken a project to develop and test a waste minimization (WM) audit procedure.

As part of this project, a total of 6 WM audits were carried out in four separate facilities. The full report presents the results of the on-site WM audits performed at two electroplating facilities that generate cyanide-bearing wastes. The report also describes the WM audit procedure as it has developed from the initial (pre-project) sequence of steps, to the modified (post-project) sequence that reflects the experience gained during this project. The 4 other audits, 2 dealing with solvent wastes and 2 dealing with heavy metal and corrosives wastes, are discussed in two separate reports.

Waste Minimization Audit Procedure

The main objective of the full report is to provide useful guidelines for the conduct of a WM audit. The following sections discuss how a WM audit fits into an overall WM program, and provide brief descriptions of the principal elements of a WM audit.

The Role of the WM Audit in a WM Program

The primary objective of a waste minimization program is to reduce the quantity and/or toxicity of waste effluents leaving the production process. The essential elements of a WM program include the initiation and planning of the program, the planning and execution of a WM audit, and the implementation of the recommended measures that emerge from the audit process.

During the program initiation phase, the commitment of top management to reduce waste generation must be established, which results in the development of an organizational structure for the WM program and in the setting of waste reduction goals for the entire organization. The next step involves characterization of waste generation rates and waste characteristics. The program planning step follows, with the selection of the audit team(s) to carry out the actual auditing phase. The auditing process constitutes the most important element of the overall WM program, since it provides the key inputs for the generation of WM options, as well as for the decisions of which waste minimization measures should be implemented. Following the audit, selection of options for implementation are made based on feasibility analysis. Finally WM measures go through the sequence of design, procurement, construction, startup, and performance monitoring.

Waste Minimization Audit Procedure

The execution of a waste minimization audit can be divided into three distinct phases, as shown in Table 1. The overall objective of the pre-audit phase is to gather and analyze the information necessary to select a waste stream(s) for the facility audit. The audit phase follows, the objective of which is to develop a comprehensive set of WM options and to screen them. The product of the audit phase is a list of options selected for further evaluation. A technical and economic feasibility analysis is performed for each selected option during the post-audit phase of the program. This phase ends with the preparation of a final report. The following paragraphs provide a brief description of each audit step.

1. Preparation for the audit

The objective of this step is to gain background information about the facility to be audited. Preparation should include examination of information sources related to the processes, operations, and waste management practices at the facility. The result of proper preparation should be a well-defined needs list, inspection agenda, or a checklist detailing what is to be accomplished, what questions or issues need to be resolved, and what information needs to be gathered. The needs list should be provided to the facility before the actual site visit to allow the facility personnel to assemble the materials needed by the audit team in advance.

2. Pre-audit meeting

The next step is a pre-audit meeting with plant personnel. This initial contact should include solicitation of plant personnels' views on the focus and function of the audit. The information needs identified in the previous step should be discussed. A tour of the facility should be performed to familiarize the audit team with the operations performed. During this meeting, it is important to establish a key facility contact.

3. Data compilation and waste stream selection

Selecting the principal waste streams or waste producing operations for the audit provides the audit team with the focus for the effort. The criteria used for waste stream selection include waste composition, quantities, degree of hazard, method and cost of disposal, perceived potential for minimization, and compliance status.

After all pertinent data are collected, they should be assembled in the form of a written facility description. The description should include facility location and size, description of pertinent operations or processes, and a description of the waste streams centering on sources, generation rates, and current methods of management. The report should include a written justification for selection of a waste stream(s) for study.

4. Audit inspection

The audit inspection is the ultimate step in the information gathering process. The governing objective of this step is to evolve a fuller understanding of primary and secondary causes of waste generation for the selected waste streams, and to cover the items missed in the pre-audit phase. The audit inspection must result in a clear understanding of waste generation causes. Useful guidelines for this step include having a detailed inspection agenda ready in advance, scheduling the

Table 1. Recommended Waste Minimization Audit Procedure

Program Phase	*Activities*	*Product*
Pre-Audit	*1. Preparation for the audit*	• *needs list/inspection agenda*
	2. Pre-audit meeting and inspection	• *notes*
	3. Data compilation and waste stream selection	• *facility and process description*
		• *waste description*
		• *rationale for selection*
Audit	*4. Facility inspection*	• *notes*
	5. Generation of a comprehensive set of WM options	• *list of proposed options with written rationale*
	6. Options evaluation	• *independent options ratings by audit team and by plant personnel followed by joint review*
	7. Selection of options for feasibility analyses	• *list of selected options*
		• *options interim report*
Post-Audit	*8. Technical and economic feasibility analysis*	• *study or budget grade estimates of capital and operating costs; profitability analysis*
	9. Final report preparation	• *final report with recommendations*

inspection to coincide with the particular operation that is of interest, obtaining permission to interview plant personnel directly, obtaining permission to photograph the facility, observing the "housekeeping" aspects of operation, and assessing the level of coordination of environmental activities between various departments.

5. Generation of WM options

The objective of this step is to generate a comprehensive set of WM options. It is important at this point to list as large a number of options as possible, including WM measures currently in place in the audited facility. Option generation should follow a hierarchy to reflect the environmental desirability of source reduction over recycling, and of recycling over treatment. Options can be generated by examining the technical literature, through discussion with manufacturers of equipment or suppliers of process input materials, and through the use of a checklist. Table 2 provides a checklist suitable for electroplating wastes.

6. Options evaluation

Each of the options postulated in the preceding step must undergo a preliminary qualitative evaluation. The objective of this evaluation is to weed out the measures that do not merit additional consideration and to rank the remaining measures in the order of their overall desirability. The evaluation should consider aspects such as waste reduction effectiveness, extent of current use in the facility, industrial precedent, technical soundness, cost, effect on product quality, effect on plant operations, implementation period, and implementation resources availability. It is recommended that the evaluation process be performed independently by both the audit team and the host facility personnel. A rating system has been developed to rank the measures in a consistent pattern and to provide a framework for resolving the differences in opinions.

7. Selection of options for feasibility analysis

Following the evaluation process by the two independent groups, the two sets of ratings are compared and discussed in a joint meeting in order to develop ratings which are mutually acceptable. The product of this meeting is a WM options list with revised ratings. The final ratings are then used as a basis for the selection of options for additional feasibility analysis. The number of measures promoted to the

Table 2. *Source Reduction Options Checklist for Cyanide Wastes from Electroplating Operations*

Options	*Comments*
Drag-out minimization	— *By reducing drag-out, less of the plating solution leaves the tank.*
Workpiece positioning	— *Proper positioning of the part of the rack reduces solution drag-out.*
Withdrawal speed and drainage	— *Slow speeds reduce drag-out. Parts should be allowed to drain over tank.*
Drag-out recovery	— *Drain boards and drip tanks can be used to recover plating solutions.*
Concentration	— *Reducing the concentration of the bath reduces losses due to drag-out.*
Temperature	— *Increased temperature reduces solution viscosity/surface tension.*
Surfactants	— *Lower the surface tension of the solution which reduces drag-out.*
Extension of bath life	— *Reduces the frequency of spent bath replacement.*
Drag-in reduction	— *Efficient rinsing prevents cross-contamination of solutions.*
Deionized water	— *Reduces the build-up of calcium and magnesium ions in the bath.*
Impurity removal	— *Can be performed by chemical precipitation, freezing (carbonates), or by filtering (particulates).*
Rack maintenance	— *Corrosion and salt deposits on the rack can contaminate plating baths.*
Anodes	— *Use of purer anodes and bags will prevent insoluble impurities in the anodes from entering the bath. Anodes should be removed when not in use.*
Return solution	— *Some manufacturers of plating solutions will reprocess spent baths.*
Minimization of rinse water	— *Reducing flow promotes recovery of metals and makes treatment more effective.*
Automatic flow control	— *Reduces water use while insuring required degree of rinsing.*
Agitation	— *Increases rinsing efficiency which reduces the volume of water needed.*
Multiple tanks	— *Counter-current rinsing can reduce water requirements by 60 to 90 percent.*
Spray/fog nozzles	— *More efficient than rinsing a part in a tank of water.*
Closed-loop rinsing	— *Susceptable to impurity build-up and may require the use of a recovery system, e.g., evaporation, ion exchange, reverse osmosis, electrodialysis.*
Non-cyanide solutions	— *Eliminates the generation of a cyanide-bearing waste.*
Copper plating	— *Pyrophosphate copper plating solution may be used as a replacement.*
Cadmium plating	— *Substitutes include cadmium fluoborate and acid sulfate cadmium baths.*
Silver stripping	— *May be performed with potassium nitrate and ammonium hydroxide.*
Alternate plating techniques	— *Eliminates the use of hazardous plating solutions.*
Ion vapor deposition	— *Can be used to plate parts with cadmium or aluminum. Required equipment is very complex and expensive.*
Good operating practices	— *Helps to minimize waste generation through procedural policies.*
Segregation	— *Proper segregation can prevent mixing of hazardous and non-hazardous waste.*
Training/supervision	— *Operator awareness can help identify and eliminate wasteful practices.*
Spill and leak prevention	— *Reduces the loss of materials and the generation of clean-up wastes.*
Maintenance	— *Preventive and corrective maintenance reduces spills, leaks, and upsets.*
Material tracking/control	— *Provides the facility with accurate material balances which can be used to identify and quantify material and waste handling problems.*

feasibility evaluation stage depends on the time, budget, and resources available for such study.

8. Analysis of technical and economic feasibility

The specific WM options selected for additional evaluation must be analyzed. Study-grade (e.g., ±30% accuracy) estimates for the capital and operating costs can be obtained from preliminary vendor information or factored estimation techniques. Once the costs are obtained, the analysis is focused on an estimation of profitability, based on conventional methods (payback period, internal rate of return, or net present value).

9. Final report preparation

As the concluding step of a WM audit, a final report should be prepared to summarize all the pertinent data, results, and recommendations.

Results of Waste Minimization Audits for Cyanide Wastes

Waste minimization audits were conducted at two electroplating facilities generating cyanide-bearing wastes. The following sections summarize the reports prepared for each facility.

Facility C-1A/B

Facility C-1A/B, located in Southern California, is a major aviation, industrial, and seaport complex supporting anti-submarine aircraft, helicopters, and aircraft carriers of the Pacific Fleet. Cyanide wastes are generated from various operations associated with the plating shop. The principal metals plated at this facility are chromium, nickel, aluminum, copper, cadmium, and silver.

Plating is performed using racks or barrels. The sequence of unit operations is very similar for the plating of different type of metals and includes alkaline cleaning, acid cleaning, stripping (if the removal of old coating is required), and electroplating. Each operation is followed by a single flowing water rinse.

The cyanide loss and subsequent waste stream generation is due to (a) drag-out of plating/stripping solutions, which enter the rinse water, and (b) plating solution filtrate, which is retained in the filtering medium and disposed of as solid waste. Owing to a high drag-out rate, the solutions are replenished frequently and do not have to be replaced periodically. Out of 650,000 gallons of wastewater generated daily, about 5 percent is estimated to originate from cyanide-based plating operations.

A total of 31 source reduction options were considered and grouped into six distinct categories based on the similarity in end-result of the methods. The categories include drag-out minimization, bath life extension, rinse water minimization, substitution of non-cyanide solutions, substitution of alternate plating metals or techniques, and good operating practices. Each measure was then rated based on a pre-established rating system.

Through a joint review of the ratings of each proposed waste minimization option by the audit team and facility personnel, a set of high-ranking options was selected for additional evaluation and analysis. The options chosen as candidates for further analysis were reduction of drag-out using drain boards and extension of bath life through impurity removal, reduction of drag-out using drain boards and extension of bath life through conversion to mechanical agitation, recovery of drag-out using still rinsing, reduction of water usage using spray rinsing, and substitution of non-cyanide cadmium plating solutions. Table 3 summarizes the results obtained from the economic feasibility study associated with these options.

A preliminary economic feasibility study was independently performed for 5 waste minimization options selected from among 31 options initially considered. Since the payback periods calculated for these options did not exceed a "rule-of-the-thumb" 3 year value, the options appear feasible and may be considered for implementation.

Facility C-2

Facility C-2 is a small shop located in Southern California whose main business is refinishing decorative items. The principal metals plated at this facility are nickel, brass, silver, and gold.

The basic operations performed at the plating shop include paint stripping, cleaning, electroplating, drying, and polishing. All operations are performed manually.

Table 3. *Summary of Economic Feasibility Study for Facility C-1A/B*

Control Category	Waste Reduction Method	Waste Reduction (%)	Capital Cost ($)	Monthly Cost ($/month)	Monthly Savings ($/month)	Pay-back Period (month)
Drag-out Minimization	Use of drain boards	90	890	—	784	1.1
	Use of drain boards/ impurity removal	90	1103	1820	784	—
	Use of drain boards/ mechanical agitation	90	7030	—	784	9.0
	Still rinsing					
	— Copper	40	560	—	202	2.8
	— Cadmium	40	1680	—	58	2.4 yrs
	— Silver	40	2800	—	89	2.6 yrs
Bath Life Extension	Impurity removal	—	213	1820	—	—
	Mechanical agitation	—	6140	—	—	—
Rinse Water Minimization	Spray rinsing	50	11685	—	440	2.2 yrs

Cyanide-bearing waste is generated from silver stripping, from silver, gold, brass, and copper electroplating, and from the associated rinsing operations. The principal waste streams include wastewater (e.g., overflows from the continuous rinse tanks and water used for floor washings) and plating tank filter waste. Wastewaters from non-cyanide sources such as paint stripping, buffing, and floor washing, and from electroplating operation are routed to a common sump. The contents of the sump (approximately 300-400 gallons of sludge) are pumped out periodically and disposed of as hazardous waste. Owing to high drag-out rate, plating solutions are adequately purged and thus need not be replaced on a periodic basis.

A total of 23 options were initially postulated for the reduction of cyanide-bearing waste from the plating shop. As was the case for facility C-1A/B, the WM options were grouped into six categories: drag-out minimization; bath life extension; rinse water minimization; substitution of non-cyanide solutions; good operating practices; and plant layout alterations. Most of the proposed options are the same as those proposed for facility C-1A/IB, with the exception of the options involving good operating practices and plant layout alteration (both are site-specific measures). The options were rated by the project staff and were then presented to the facility personnel for review.

High-ranking options were selected for feasibility evaluation. These included reduction of drag-out using drain boards, extension of bath life through the use of deionized water, reduction of water usage using spray rinsing, and use of plastic media blasting instead of paint stripping (in conjunction with waste stream segregation). Table 4 presents a summary of the results obtained from the economic feasibility study of these options.

A preliminary feasibility study was performed for 4 waste reduction options selected from among 23 options initially considered. Of these four options, only spray rinsing appears to be economically unviable. The other options appear feasible and may be considered for future implementation.

Observations and Recommendations

The following observations and recommendations were made as the result of the pilot audits:

- For the two facilities audited, the availability of the required process documentation was not satisfactory. Experience with these and other sites indicated that the availability and quality of the information varies significantly. Much information is available, however, from outside sources such as vendors, chemical suppliers, and literature.
- Pre-audit activities, particularly the pre-audit site visits, were found to be extremely important in facilitating the audit process. Cooperation by the plant staff was improved when the audit team spent more time getting to know the host facility staff and how their organization functioned.
- Participation in the options ratings process is much improved when the host facility personnel are required to independently develop ratings of each of the WM options under consideration.
- Good operating practices recommendations must be presented with their economic dimension stressed in order to retain the interest of the host facility personnel. Otherwise, they can be seen as trivial and trite.

This Project Summary was prepared by staff of Versar, Inc., Springfield, VA.
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The complete report, entitled "Waste Minimization Audit Report. Case Studies of Minimization of Cyanide Waste from Electroplating Operations," (Order No. PB 87-229 662/AS; Cost: $18.95, subject to change) will be available only from:
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The EPA Project Officer can be contacted at:
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Table 4. *Summary of Economic Feasibility Study for Facility C-2*

Description of Options	Method	Percent Waste Reduction (%)	Capital Cost ($)	Monthly Cost ($/month)	Monthly Savings ($/month)	Pay-back Period (month)
1. Drag-out Minimization	Use of drain boards	50	315	—	241	1.3
2. Extension of Bath Life*	Use of deionized water	50	582	38	241	2.9
3. Rinse water Minimization	Use of spray rinsing	50	2,825	—	29	8.1 years
4. Good Operating Practices	Use of plastic media blasting	90	17,900	2,519/yr	6,607/yr	4.4 years

* *Economic analysis was performed in conjunction with the implementation of drain boards.*

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