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Guides to Pollution Prevention

The Photoprocessing Industry

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Risk Reduction Engineering Laboratory
and
Center for Environmental Research Information
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

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Notice

This guide has been subjected to the U.S. Environmental Protection Agency's peer and administrative review and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

This document is intended as advisory guidance only to photoprocessors in developing approaches for pollution prevention. Compliance with environmental and occupational safety and health laws is the responsibility of each individual business and is not the focus of this document.

Worksheets are provided for conducting waste minimization assessments of photoprocessing operations. Users are encouraged to duplicate portions of this publication as needed to implement a waste minimization program.

Foreword

Photoprocessing laboratories primarily generate aqueous wastes from process operations. The most significant contaminant is silver, which may be present as silver thiosulfate complex. Some aqueous wastes also contain other chemicals. Technology exists to recover silver, as well as certain other chemicals. Solid wastes are primarily paper and fabricated items such as film cassettes, spools, and cartridges.

Reducing these wastes at the source, or recycling usable materials, will benefit photoprocessors by reducing raw material costs, waste disposal costs, and potential liabilities associated with hazardous wastes. This guide provides an overview of photoprocessing processes and operations that generate waste and presents options for minimizing waste generation through source reduction and recycling. It also includes worksheets to assist photoprocessors in performing waste minimization self-assessment.

Contents

Acknowledgments

This guide is based on a waste audit study for the photoprocessing industry performed by Arthur D. Little, Inc., for the California Department of Health Services, under the direction of Benjamin Fries of the Alternative Technology Division, Toxic Substances Control Program. Teresa Harten of the U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, was the project officer responsible for the preparation of this manual, which was edited and produced by Jacobs Engineering Group, Inc.

We would like to thank the following people, whose review of this guide contributed substantially to its development:

William F. Wescott	-	Arthur D. Little, Inc.
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Much of the information in this guide that provides a national perspective on the issues of waste generation and minimization was provided originally to the U.S. Environmental Protection Agency by Versar, Inc. and Jacobs Engineering Group, Inc. in *Waste Minimization-Issues and Options, Volume II*, Report No. PB87-114 369 (1986).

Section 1
Introduction

This guide is designed to provide photoprocessors with waste minimization options appropriate for this industry. It also provides worksheets designed to be used for a waste minimization assessment of a photo lab, to be used in developing an understanding of the waste generating processes and to suggest ways to reduce the waste. The guide should be used by photoprocessing companies, particularly their operators and environmental engineers. Others who may find this document useful are regulatory agency representatives, industry suppliers, and consultants.

In the following sections of this manual you will find:

- A profile of the photoprocessing industry and the processes used by the industry (Section 2);
- Waste minimization options for photoprocessing firms (Section 3);
- Waste minimization assessment guidelines and worksheets (Section 4);
- Appendices, containing:
  - Case studies of waste generation and waste minimization practices of photoprocessors;
  - Where to get help: additional sources of information.

The worksheets and the list of waste minimization options were developed through assessments of three photoprocessing firms, commissioned by the California Department of Health Services (Calif. DHS 1989). The operations, manufacturing processes, and waste generation and management practices were surveyed, and their existing and potential waste minimization options were characterized.

Overview of Waste Minimization

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Wastes Amendments to the Resource Conservation and Recovery Act (RCRA). As the federal agency responsible for writing regulations under RCRA, the U.S. Environmental Protection Agency (EPA) has an interest in ensuring that new methods and approaches are developed for minimizing hazardous waste and that such information is made available to the industries concerned. This guide is one of the approaches EPA is using to provide industry-specific information about hazardous waste minimization. The options and procedures outlined can also be used in efforts to minimize other wastes generated in a business.

In the working definition used by EPA, waste minimization consists of source *reduction* and *recycling*. Of the two approaches, source reduction is considered environmentally preferable to recycling. While a few states consider *treatment* of hazardous waste an approach to waste minimization, EPA does not, and thus treatment is not addressed in this guide.

Waste Minimization Opportunity Assessment

EPA has developed a general manual for waste minimization in industry. *The Waste Minimization Opportunity Assessment Manual* (USEPA 1988) tells how to conduct a waste minimization assessment and develop options for reducing hazardous waste generation. It explains the management strategies needed to incorporate waste minimization into company policies and structure, how to establish a company-wide waste minimization program, conduct assessments, implement options, and make the program an on-going one.

A Waste Minimization Opportunity Assessment (WMOA), is a systematic procedure for identifying ways to reduce or eliminate waste. The four phases of a waste minimization opportunity assessment are: planning and organization, assessment, feasibility analysis, and implementation. The steps involved are shown in Figure 1 and are presented in more detail on page 3. Briefly, the assessment consists of a careful review of a plant's operations and waste streams and the selection of specific areas to assess. After a particular waste stream or area is established as the WMOA focus, a number of options with the potential to minimize waste are developed and screened.

The technical and economic feasibility of the selected options are then evaluated. Finally, the most promising options are selected for implementation.

Planning and Organization Phase

Essential elements of planning and organization for a waste minimization program are: getting management commitment for the program; setting waste minimization goals; and organizing an assessment program task force.

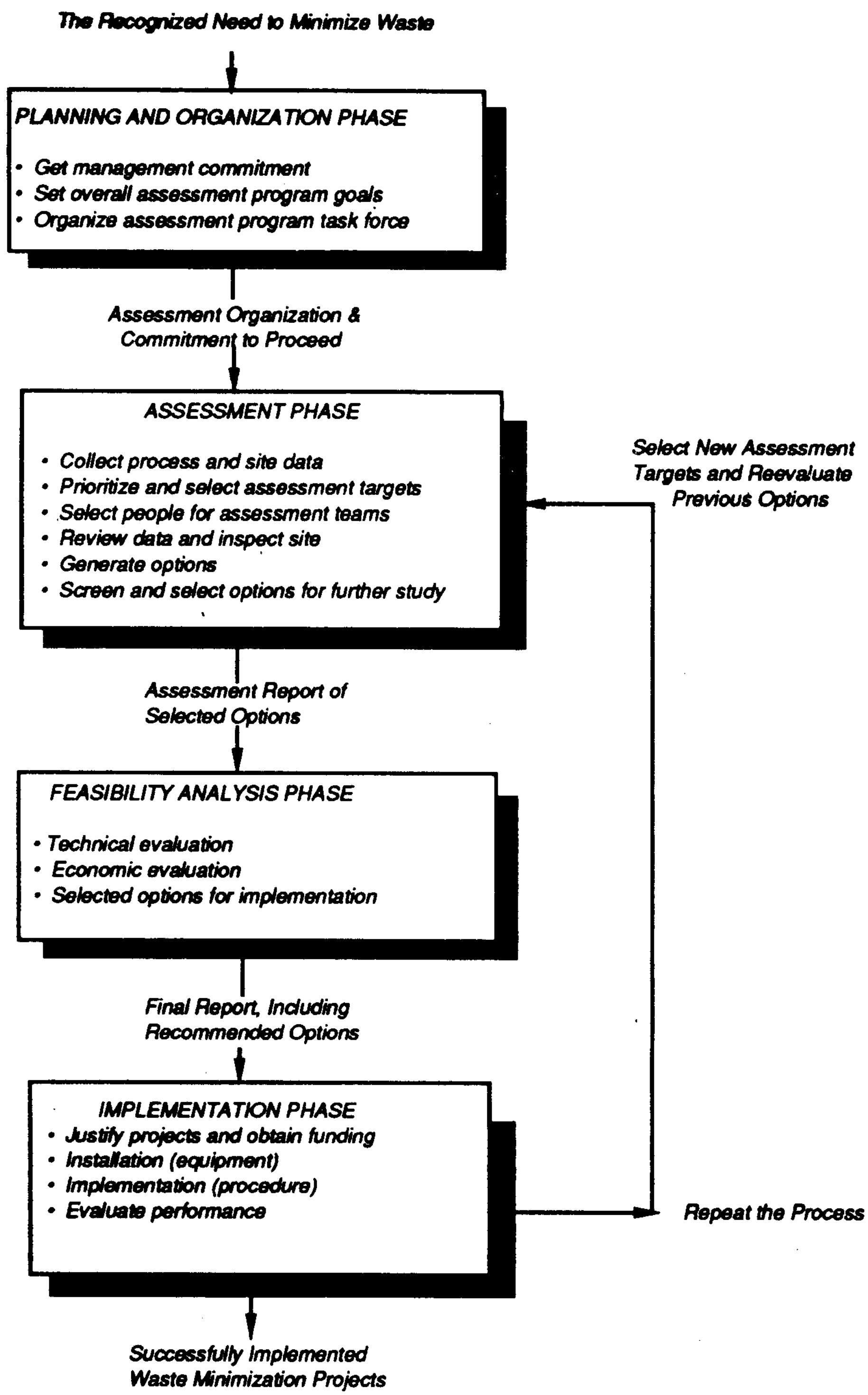

Figure 1. The Waste Minimization Assessment Procedure.

Assessment Phase

The assessment phase involves a number of steps:

- Collect process and site data
- Prioritize and select assessment targets
- Select assessment team
- Review data and inspect site
- Generate options
- Screen and select options for feasibility study

Collect process and site data. The waste streams at a facility should be identified and characterized. Information about waste streams may be available from hazardous waste manifests, National Pollutant Discharge Elimination System (NPDES) reports, routine sampling programs, and other sources.

Developing a basic understanding of the processes that generate waste at a site is essential to the WMOA process. Flow diagrams should be prepared to identify the quantity, types, and rates of waste generating processes. Also, preparing material balances for various processes can be useful in tracking various process components and identifying losses or emissions that may have been unaccounted for previously.

Prioritize and select assessment targets. Ideally, all waste streams in a business should be evaluated for potential waste minimization opportunities. With limited resources, however, the owner or manager may need to concentrate waste minimization efforts in a specific area. Such considerations as quantity of waste, hazardous properties of the waste, regulations, safety of employees, economics, and other characteristics need to be evaluated in selecting the target streams.

Select assessment team. The team should include people with direct responsibility and knowledge of the particular waste stream or area of the facility being assessed. Operators of equipment and the person who sweeps the floor should be included, for example.

Review data and inspect site. The assessment team evaluates process data in advance of the inspection. The inspection should follow the target process from the point where raw materials enter to the points where products and wastes leave. The team should identify the suspected sources of waste. This may include the production process; maintenance operations; and storage areas for raw materials, finished product, and work in progress. The inspection may result in the formation of preliminary conclusions about waste minimization opportunities. Full confirmation of these conclusions may require additional data collection, analysis, and/or site visits.

Generate options. The objective of this step is to generate a comprehensive set of waste minimization options for further consideration. Since technical and economic concerns will be considered in the later feasibility step, no options are ruled out at this time. Information from the site inspection, as well as trade associations, government agencies, technical and trade reports, equipment vendors, consultants, and plant engineers and operators may serve as sources of ideas for waste minimization options.

Both source reduction and recycling options should be considered. Source reduction may be accomplished through good operating practices, technology changes, input material changes, and product changes. Recycling includes use and reuse of waste, and reclamation.

Screen and select options for further study. This screening process is intended to select the most promising options for full technical and economic feasibility study. Through either an informal review or a quantitative decision-making process, options that appear marginal, impractical or inferior are eliminated from further consideration.

Feasibility Analysis Phase

An option must be shown to be technically and economically feasible in order to merit serious consideration for adoption at a business. A technical evaluation determines whether a proposed option will work in a specific application. Both process and equipment changes need to be assessed for their overall effects on waste quantity and product quality. An economic evaluation is carried out using standard measures of profitability, such as payback period, return on investment, and net present value. As in any other project, the cost elements of a waste minimization project can be broken down into capital and operating costs. Savings and changes in revenue also need to be considered.

Implementation Phase

An option that passes both technical and economic feasibility reviews should be implemented. It is then up to the WMOA team, with management support, to continue the process of tracking wastes and identifying opportunities for waste minimization by periodic reassessments. Such ongoing reassessments and the initial investigation of waste minimization opportunities can be conducted using this manual.

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California DHS. April 1989. *Waste audit study: Photoprocessing industry.* Report prepared by Arthur D. Little, Inc. for the Alternative Technology Section, Toxic Substances Control Division, California Dept. of Health Services.

USEPA. 1988. *Waste minimization opportunity assessment manual.* Hazardous Waste Engineering Research Laboratory, Cincinnati, Ohio, EPA/625/7-88/003.

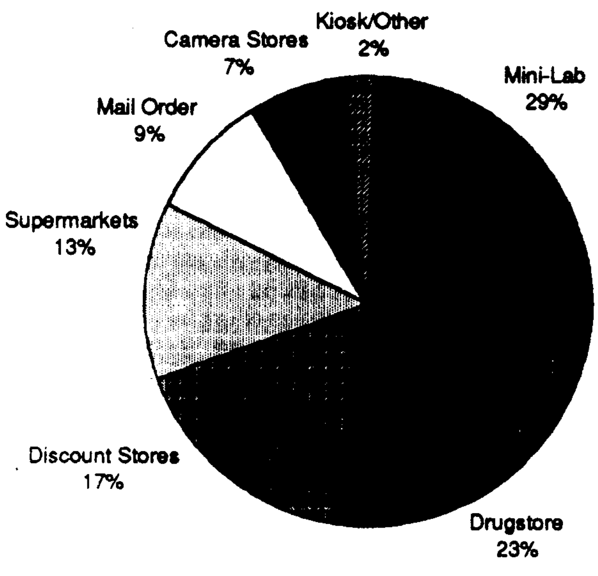
Section 2
Photoprocessing Industry Profile

Industry Description

The photoprocessing industry consists of businesses which develop and finish photographic film. This industry is included in Standard Industrial Classification (SIC) code 7382. In 1988, U.S. consumers spent $4.86 billion on photo finishing compared to $4.4 billion in 1987 (U.S. Dept. of Commerce 1988). The rate of revenue growth for finishing has far outstripped that for film, cameras, and other photo equipment for at least the last decade. The industry is diversified both geographically and in terms of unit size. Figure 2 illustrates the market share for various types of processors, based on number of film rolls processed in 1987. The largest share belongs to mini-labs, which are on-site photoprocessors. This segment has grown from 5,200 labs in 1984 to 14,700 in 1987 (end-of-year figures).

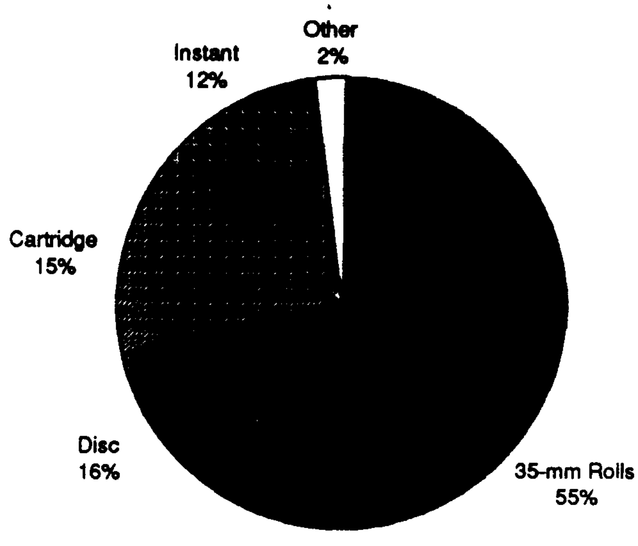
Figure 3 illustrates the market share by film type. The most popular type is 35 mm film. Instant film is not processed and is outside the scope of this study. Disc film use is declining. Eastman Kodak, a major supplier, has withdrawn from this part of the camera market. Cartridge film use is strong because this type of camera is frequently offered by retailers as a promotion.

Nearly all of the consumer-oriented films are based on silver as the photo-active chemical. Other types of films are diazo, vesicular photopolymer, and electrostatic (Calif. DHS 1989b), which are not covered by this guide. These have specific commercial markets and are likely to be processed only by specialized (often in-house) labs.



Reference: Standard & Poor's. 1990 Industry Surveys.

Figure 2. Share of Photofinishing Market. Based on number of rolls (1987).



Reference: Standard & Poor's. 1990 Industry Surveys.

Figure 3. Types of Film Processed. Based on number of rolls (1987)

Process Descriptions

The processing of photographic film and paper requires the use of a number of chemicals to develop and produce finished photographic goods. The waste streams generated vary widely according to the type and volume of processing. Photoprocessing is dominated by color print film, prints, and slides, with only about 10 percent of the market involving black-and-white processing. Because color processing usually represents a greater production volume of the operations at a given location, it usually generates a larger waste stream volume. An increasing portion of the color market is being taken by mini-labs, which are automated machines that occupy little space. These machines are the ones used by the popular one-hour developing centers. The waste stream volume from most one-hour developing centers has been greatly reduced, because most centers have converted to "washless" or "plumbingless" processing, which does not use a conventional wash cycle.

Color Processing

Film and paper used for color photography consist of three separate layers of photosensitive emulsion with intermediate layers. Each layer is coated on clear film base or on paper. Each emulsion layer is sensitive to either red, green or blue light due to the presence of selective dyes in the emulsion. Intermediate layers filter out other wavelengths, so that the silver halide salts in each photosensitive layer are exposed only by light of the specific color. A colorless dye-forming coupler is present along with the silver halide crystals in each emulsion layer. When processed in a color-developing solution, an image of "developed silver" is formed in each layer. The exposed silver halide crystals are reduced to metallic silver, while simultaneously producing oxidized developer molecules. The oxidized developer reacts with the dye-forming coupler to produce a dye which is complementary in color to the light to which the emulsion layer is sensitive. The intensity of the dye formed in a particular portion of the image is dependent on the quantity of oxidized developer, which is in turn proportional to the extent of exposure in that area.

A bleach bath renders the color image visible by removing the black metallic silver image, converting the metallic silver back to a silver halide. All of the silver on the film, whether exposed or not, can then be dissolved and removed in the fixer bath. The dye is retained in each layer of the film so that a negative (complementary) color image remains. Some processes combine the bleach and fix processes in a single solution, termed bleach-fix or "blix." It is a common practice to introduce the film into a stabilizer bath after the fixer solution to equilibrate the emulsion and increase the stability of the dye image to light. A schematic diagram of the color negative film process is shown in Figure 4.

Positive color prints can be made from the film negative recorded by the camera by exposing color paper or other suitable print medium to light through the developed film. The print medium, which contains the same combination of color-sensitive emulsion layers as does the film, is then processed through a similar sequence of solutions to obtain the final print, as illustrated by Figure 5.

For color slides, a positive color image is produced directly on the film by reversal processing. The exposed color film is first subjected to black-and-white processing to produce a negative image consisting only of metallic silver. After washing, the film is immersed in a reversal bath that renders the remaining silver salts developable. The film is then processed in a color developer that reduces the remaining silver salts and produces a positive dye image. Then a sequence of bleach, fixer, and wash steps produces the final color transparency.

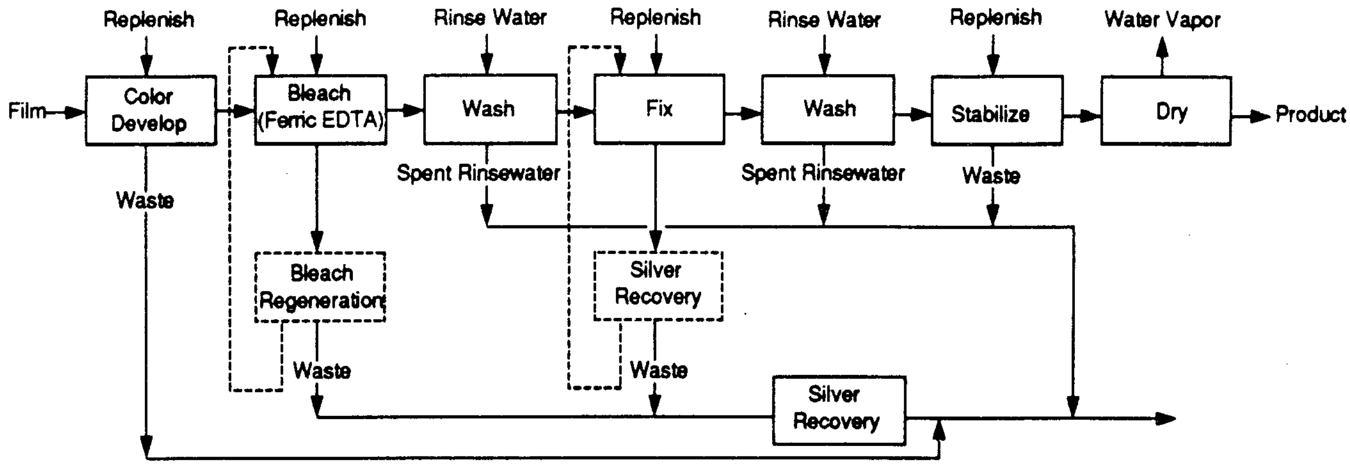
Color prints can be made from slides by a similar reversal process. Alternately, prints can be prepared by first producing a film negative from the slide, and then printing from this negative in the usual fashion. Figure 6 is a schematic diagram depicting both slide and reversal print operations.

Cinemagraphic film processing is similar to processing of color print or slide film. In commercial operations, a large number of copies are made from one film. A print or "negative image" film is used for the original exposure and then used to make film copies (much as print film is used to make prints). Amateur film processing, which usually results in only one copy of the film, uses film much like slide film that is exposed and processed, producing the positive image on the originally-exposed film.

Black-and-White Processing

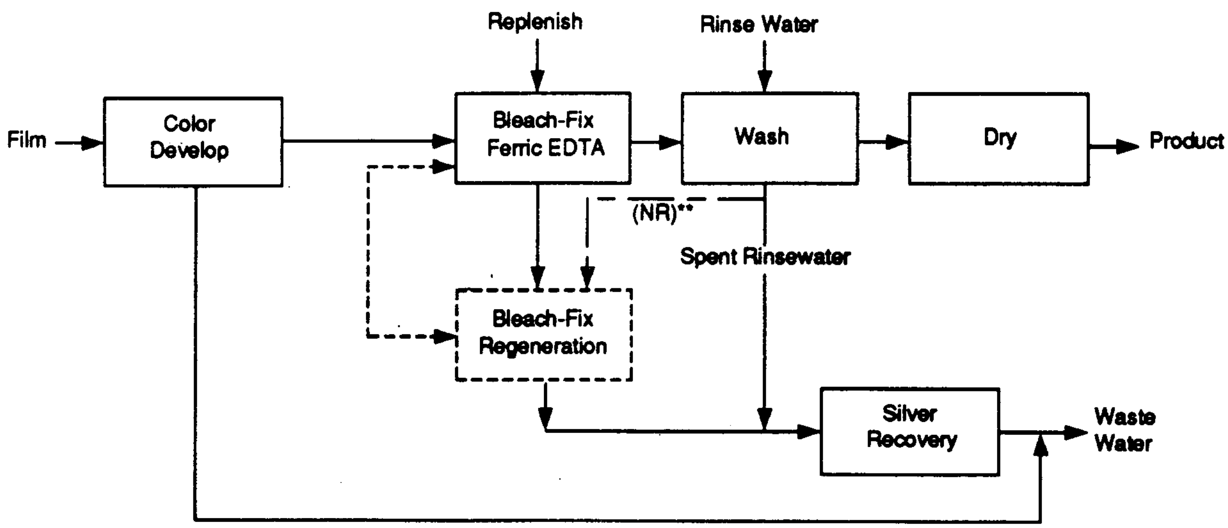
The photosensitive medium used for black-and-white processing is an emulsion composed of a dispersion of fine silver halide crystals in a matrix of gelatin. This emulsion is applied in a layer approximately 1/1000 of an inch thick on a supporting material, either paper or clear plastic film. Brief exposure to small quantities of light produces a chemical change in the silver halide crystals, which allows the silver ions in the exposed crystals to be converted to metallic silver at a faster rate than in unexposed crystals. By focusing the light through the camera lens, the pattern of exposed crystals corresponds to the image from which light is reflected. At this point, the exposed silver halide crystals are termed "developable." When the film is subsequently immersed in the developing solution, an alkaline solution of organic reducing agents, the exposed silver halide crystals are reduced to metallic silver. The silver is dark in color and produces a negative image. The most commonly used developing agents are metol (p-methylaminophenol sulfate) and hydroquinone (p-dihydroxybenzene) or 1,4-dihydroxybenzene.

The chemistry of development is extremely complex. For example, hydroquinone in ordinary sulfite-containing developers (sodium sulfite is added to most developers as a preservative) is oxidized to a semi-quinone free radical, and then reacts with sulfite to form mono- and di-sulfonates. These reaction products may be isolated along with quinone, sodium sulfate (Na_2SO_4), and many other compounds associated with the other ingredients, e.g., metol, sodium carbonate, and potassium bromide. For additional information on photoprocessing chemistry, various references are available (e.g. Henn, Locker, Umberger).



Reference: California DHS 1989a

Figure 4. Process: Color Negative Film.



*No Regeneration with NR Bleach Fix
**Silver Recovery from Wash Used in EP-2 Process with NR Bleach Fix

Reference: California DHS 1989a

Figure 5. Process: Color Negative Paper.

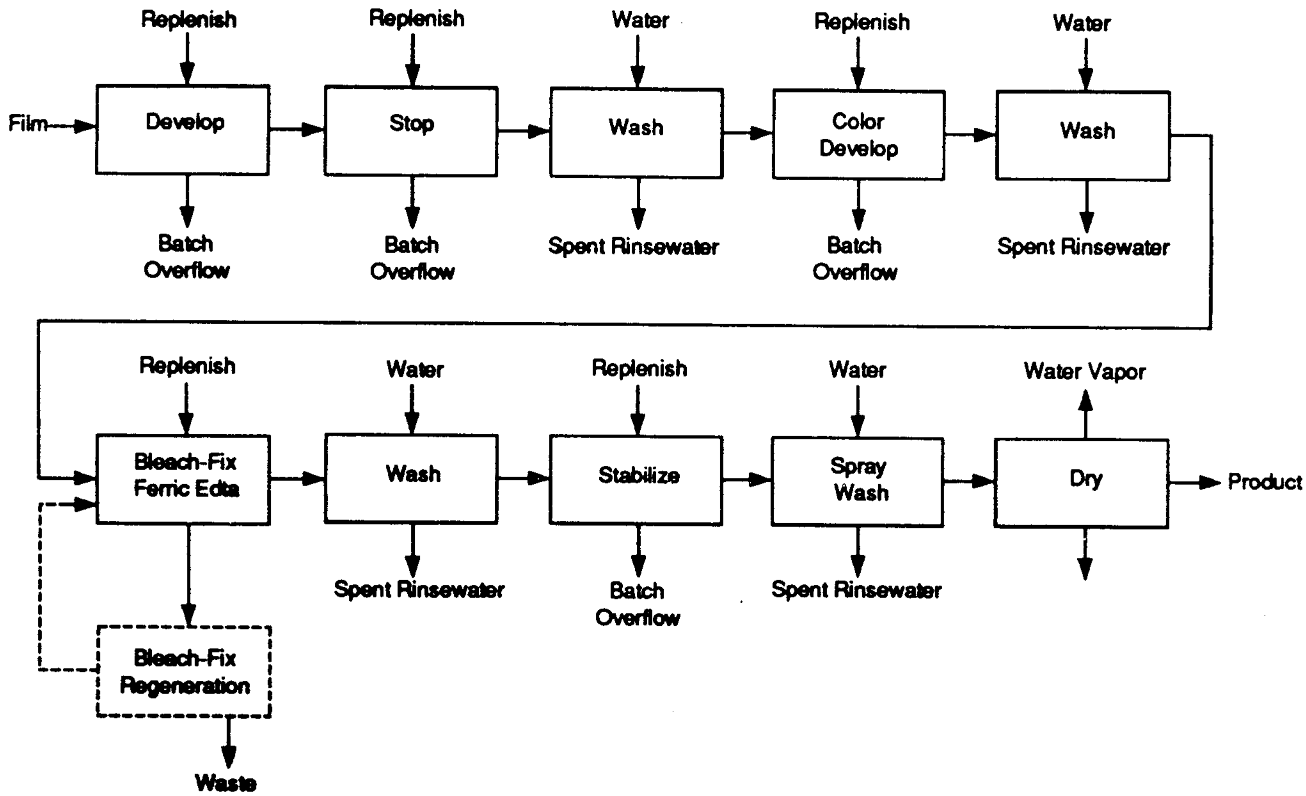


Figure 6. Process: Color Reversal Paper.

If kept in the developer bath, even the unexposed silver halide crystals can be converted to metallic silver by the developer solution. To prevent this, the action of the developer is arrested by transferring the film to a stop bath. The stop bath is a weakly acidic solution (usually acetic acid) which neutralizes any of the alkaline developer carried over on the surface of the film or in the wetted gelatin layer. Following the stop bath, the film is immersed in a fixer solution that solubilizes and removes the remaining unreacted silver salts, rendering the image on the film permanent. Fixer solution adhering to the film must be removed in a final rinse step.

The film now contains a negative image of the scene which the camera recorded. A positive print is prepared by exposing a photosensitive sheet of paper to a light source passing through the negative film image. The paper is then processed through a similar set of operations (i.e. developer, stop bath, fixer, and rinse). A diagram for black-and-white processing that applies to both film and paper is shown in Figure 7.

As more film is processed, the concentration of various reaction products gradually builds up in the developer solution. Silver and bromide ions removed from the developed film accumulate in the fixer solution, and the stop bath is gradually neutralized as the quantity of developer carried over increases. At some point, these solutions become unusable and must be discarded. The final rinse is usually conducted in a continuous flow of fresh running water. As a result, only small amounts of silver and other fixer compounds can be detected in the spent rinse water waste stream.

Black-and-white reversal film processing requires two development steps with an intermediate bleach step. Bleach solution for black-and-white processing contains sodium dichromate. Spent bleach is a hazardous waste because of its chrome content.

Manual and Automated Systems

Manual Systems

Manual systems include tray and tank processing. These are often used for low volume production such as black and white processing, enlargements, or other services that do not require, or are not amenable to, cost-effective automation. While manual processing wastes can be significantly reduced, this represents such a small volume for most businesses that the overall waste reduction impact may not be significant.

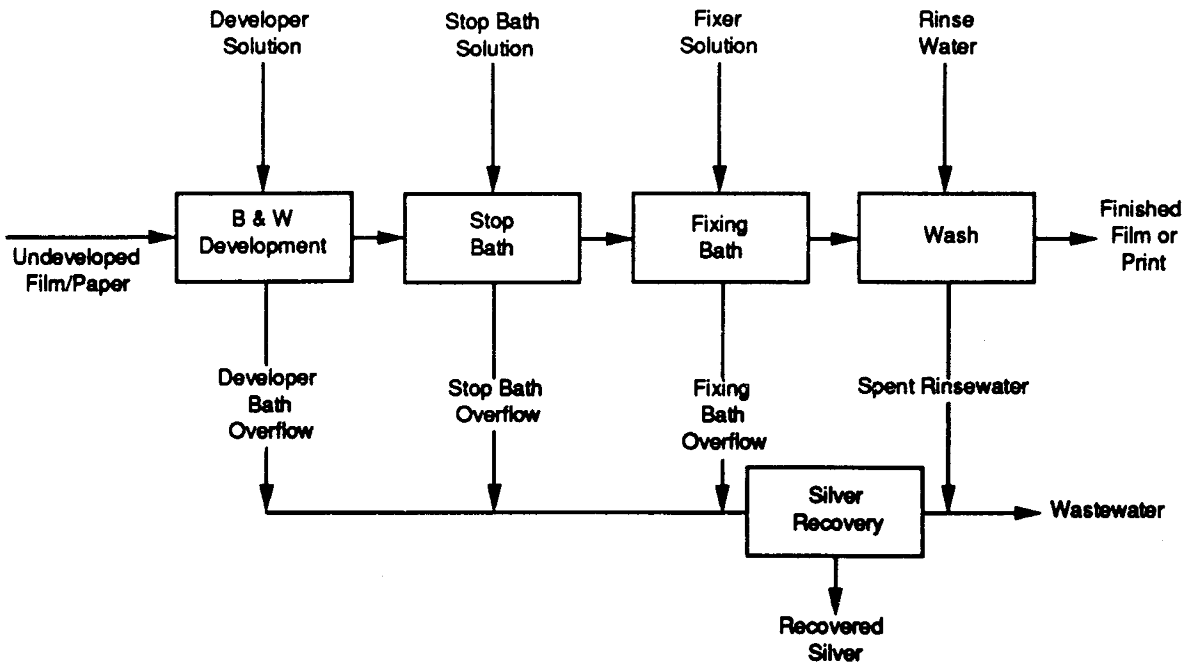


Figure 7. Black and White Development Process.

The tray method allows processing small quantities of film and papers with minimum chemical consumption. Sheets of film or paper are placed on the bottom of the shallow tray containing solution. The tray is then rocked back and forth manually to ensure that adequate fresh solution contacts the emulsion surfaces. The sheets are removed, drained, and transferred to the next processing bath. The duration of each step in the process is timed according to a prescribed schedule. Once the processing is completed, the solutions are returned to storage containers for reuse. With proper storage, solutions can be reused until chemically exhausted, as indicated by test strips.

Tanks are used for processing large quantities of film and paper sheets. This method is usually limited to sheets no larger than 8 inches by 10 inches. The sheets are suspended vertically in the tank from hangers which maintain a lateral separation. The solution level in each tank covers the entire sheet. The solution is agitated by gentle vertical movement of the hangers. When not in use, the tanks should be covered to keep foreign materials out of the processing solutions and to minimize evaporation and oxidation. Oxidation of the developer solution can be further reduced by using a tight-fitting "floating lid" of buoyant plastic and limiting the amount of time the solution is in use.

In addition, strips of camera film are often processed in tanks. The flexible film strip is inserted in a spiral slot in a reel which fits into a cylindrical tank. Inserting the film into the reel and loading the reel into the tank must be carried out in the dark. Then, in a lighted area, the solutions are added, one at a time, through a light-tight port in the cap. Following a prescribed schedule, the tank is drained and refilled with the subsequent solutions. During the final wash step, the cap can be removed to permit easier washing of the reels in the stream of water.

Automated Systems

Automated systems differ primarily by the means used to transfer the film through the sequence of solutions. The major types of transport systems are discussed in the following paragraphs.

Dip and Dunk. The films, in the form of sheets, strips, or short looped lengths, are clipped to hangers supported on a rack. The rack is removed from the processing machine to simplify loading. Once replaced in the processor, the rack holding the film is advanced by a gear chain mechanism. As the rack moves into position, it is lowered into the solution tanks so that the film is completely immersed. Agitation is provided by vertical movement of the rack to ensure continuous contact of the emulsion surface with fresh solution. As the rack continues its advance, it is automatically raised from one bath, allowed to drain, and lowered into the subsequent solution or wash tank. Finally the rack moves the film through a forced-air drying unit.

Nip Rollers. A series of small cylindrical wringers transports film or paper through the sequence of processing solutions. These rollers provide for both vertical and horizontal movement, and this method is suitable for either strips or sheets. Initially a leader strip or sheet is threaded and pulled sheets. Initially a leader strip or sheet is threaded and pulled through to a rewind station situated after the final dryer unit. Once the processing is started, movement of the film or paper through the solutions is continuous.

Belt Systems. The film or paper to be processed is supported on a belt which is conveyed through the sequence of solutions using guides and rollers. Where desirable, the material being processed can be transferred from one belt to another to allow for a greater variety of strips. Initially a leader strip or sheet is treated and pulled through to a rewind station situated after the final dryer unit. Once the processing is started, movement of the film or paper through the solutions is continuous.

High-Speed Roller. Long strips of film are mounted on a flexible support which is attached to a series of racks. A system of guides and immersed rollers conveys the film through the solutions to wash tanks. Before starting up the processor, a leader is threaded through the racks. Generally, the leader is attached to the end of the film and is always left in place between processing cycles to simplify start-up. Lengths of film to be processed, or tailing leaders, can be attached with tape or staples. High linear speeds are possible, resulting in greater throughput than can be obtained with other types of processors.

Waste Streams

Wastes generated by photoprocessors are primarily aqueous effluents. These may be categorized as: process bath wastes, color developer wastes, and bleach/fix/bleach-fix wastes (Freeman 1990). Spent rinse water is also an aqueous waste, although not specified separately in Freeman's book. They are typically combined as a single stream either to an on-site biological treatment system or via sewer to a publicly-owned treatment works (POTW). All the aqueous effluents contain silver, although in different forms and different concentrations, and some of the streams are contaminated with a variety of other chemicals. Table 1 lists waste solutions, their constituents and the associated environmental concerns.

The free silver ion is an effective bactericide, which can seriously impair biological systems. On July 1, 1976, interim federal guidelines were issued for point source discharges in the photoprocessing industry (40 CFR 459). These apply to photolabs which discharge waste waters directly into a surface water such as a stream or lake. These guidelines established limits of 0.03 pounds of silver per day per 1000 square feet of film or paper processed, and a 30 consecutive-day average of 0.015 pounds/day per 1000 square feet. However, most photolabs discharge into municipal sewer systems. Approximately half of the municipal sewer codes in the nation contain limits on silver discharge. Most of these limits range from 0.05 to 5.0 mg/L (ppm). Some municipalities have prohibited the discharge of photoprocessing effluents to their sewage systems.

The impact of silver in photoprocessing wastes is controversial. One published study indicates that there is no real threat to aquatic systems (Bard et al. 1976). Although delisting of silver is being studied by some federal authorities, some local authorities regard it as a hazardous waste. In those locations, silver-containing materials must be manifested and shipped as a hazardous waste if they contain more than 5 mg/L of silver as measured by the EPA-specific leaching test, increasing the cost for offsite reclamation.

Table 1. Aqueous Wastes from Photoprocessing

Solution	*Constituents*	*Environmental Concern*
Prehardeners, hardeners and prebaths	*Organic chemicals* *Chromium compounds*	*Oxygen demand* *Toxic metals*
Developers	*Organic chemicals*	*Oxygen demand*
Stop baths	*Organic chemicals*	*Oxygen demand*
Ferricyanide bleaches	*Ferricyanide*	*Toxic chemical*
Dichromate bleaches	*Organic chemicals* *Chromium compounds*	*Oxygen demand* *Toxic Metals*
Clearing baths	*Organic chemicals*	*Oxygen demand*
Fixing baths	*Organic chemicals* *Silver* *Thiocyanate* *Ammonium compounds* *Sulfur compounds*	*Oxygen demand* *Toxic metals* *Toxic chemicals* *Ammonia* *Possible H_2S generation*
Neutralizers	*Organic chemicals*	*Oxygen demand*
Stabilizers	*Phosphate*	*Bio-nutrients*
Sound-track fixer or redeveloper	*Organic chemical* *Ammonium compounds*	*Oxygen demand* *Ammonia*
Monobaths	*Organic chemicals*	*Oxygen demand*

In addition, photoprocessing solutions may be acidic or alkaline.

Waste streams from cinemagraphic film processing are similar to those described above with one major exception. For some cinemagraphic films, a bleach containing ferricyanide is used, and could result in appreciable concentrations of ferri- and ferrocyanide in the waste streams. Most cinemagraphic processors recover up to 99% of the ferricyanide for reuse. If not recovered, ferrocyanide can eventually be converted to free cyanide by sunlight in the presence of oxygen over a period of several weeks, and is therefore a waste constituent of concern.

Silver-bearing solid wastes include scrap film and photographic paper. Other solid wastes are film cartridges, cassettes and canisters, as well as containers for photographic chemicals.

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Section 3
Waste Minimization Options for Photoprocessors

This section discusses recommended waste minimization methods for photoprocessing operations. These methods come from both open literature and industry contacts. Waste minimization options can be classified as source reduction and recycling or resource recovery. In addition to the specific recommendations provided below, rapidly advancing technology makes it important that companies continually educate themselves about improvements that are waste reducing and pollution preventing. Information sources to help inform companies about such technology include trade associations and journals, chemical and equipment suppliers, equipment expositions, conferences, and industry newsletters. By keeping abreast of changes and implementing applicable technology improvements, companies can often take advantage of the dual benefits of reduced waste generation and a more cost efficient operation.

Table 2 summarizes the principal wastes and methods for minimizing them.

Table 2. Waste Minimization Methods for Photoprocessing

Waste Stream	*Waste Minimization Methods*
Aqueous Waste	*Use squeegees to minimize chemical carry over* *Recover silver from effluent* *Reuse fixer* *Regenerate developer* *Regenerate bleach* *Use counter current rinsing* *Use plumbingless minilabs*
Expired or Off-Spec Chemicals	*Control inventory carefully* *Store away from heat and light*
Other Solid Waste	*Store paper at cool temperature* *Recover silver from off-spec paper and from excess film* *Recycle cartridges, cassettes and spools to film manufacturer*
Air Emissions	*Use floating covers on solution tanks*

Source Reduction

The following management practices are applicable to all sizes of photoprocessing operations to minimize waste generation. They require almost no investment and have proven effective in many businesses:

- Control inventories of processing chemicals so they are used before their expiration dates.
- Make up processing solutions only in quantities needed to meet realistic processing volumes.
- Use floating lids or balls on developer solution tanks to prevent loss of potency through oxidation or evaporation.
- Improve quality control for all processes to prevent unnecessary discharges.

Squeegees can be used in all manual and some automated processing systems to wipe excess liquid from the film and paper, reducing chemical carryover from one process bath to the next by 75 percent or more (Eastman Kodak 1990). Several types are available, including wiper blades, air squeegees, vacuum squeegees, wringersling squeegees, and rotary-buffer squeegees. Belt turnarounds with soft-core rollers can be used for slow speed transport of wide films, but squeegees cannot be used on rack-and tank, basket, or drum processors (Eastman Kodak 1990). Minimizing chemical contamination of process baths increases recyclability, enhances the life of the process baths, and reduces the amount of replenisher chemicals required. Some types of squeegees may damage the film image, if it has not fully hardened.

Accurately adding and monitoring chemical replenishment of the process baths will cut down chemical waste. Process baths may be protected from oxidation by reducing exposure to air. Some smaller photo developers store chemicals in closed plastic containers. Glass marbles are added to bring the liquid level to the brim each time liquid is used. This limits the volume of air in the container, thereby extending the chemical's useful life.

Proper storage conditions are necessary to maximize the life of paper for color prints. One writer recommends storing paper in a refrigerator, if it will not be used for a few days, and in a freezer for longer storage periods. He states that he has used the same box of paper for years by freezing it (Sribnick 1986).

The photoprocessor usually receives films in rolls, cassettes, cartridges, or canisters. These are often recyclable. Eastman Kodak, for example, has collected these from some processors on a test basis, and is reportedly expanding the program. A distributor of microfilmed catalogs reuses the plastic housings returned by its customers six or seven times, before they become too worn for continued use.

Material substitution involves replacing a processing chemical with an alternate material that reduces the quantity of waste generated or the degree of hazard associated with the waste. Opportunities for this type of waste reduction in photoprocessing are limited. Alternate materials may be unavailable, more expensive, or have undesirable effects on product quality.

The "black box" nature of photoprocessing chemistry generally requires an individual operator to use established chemical packages with few options for substituting alternate materials. Photochemical manufacturers and suppliers can aid photoprocessors, however, by developing new processes which result in lower volume and lower toxicity wastes. For example, ferricyanide bleach has been replaced by ferric EDTA (ethylenediaminetetraacetic acid) complex, resulting in a less toxic waste stream (Calif. DHS 1989a).

Businesses which operate in-house labs have more flexibility for material substitution, such as using non-silver film. A company that supplies microfilms of catalogs and standards to industrial users has switched to diazo and vesicular films. However, it should be noted that these films are not considered "archival" and may not be acceptable for permanent document storage.

Recycling and Resource Recovery

Silver Recovery

Metallic silver trades as a commodity in units of Troy ounces (one Troy ounce equals 31.10 grams). In recent years the price range has typically been $4 to $6 per Troy ounce, although during the speculative fever of 1980, the price reached $50 per Troy ounce, before the market collapsed. Thus, if the market price were $6.00 per ounce, and an effluent contained 31 mg/L silver, the potential recovery value of silver would be 0.6 cents per liter or nearly 2.4 cents per gallon of effluent. Since silver recovered from photoprocessing requires further processing, reclaimers will offer somewhat less than market price for the recovered silver.

Table 3 lists the silver content in Troy ounces per square foot for several types of film, and Table 4 shows the surface area for film rolls. The quantity of silver entering the facility can be estimated based on the number of rolls processed. However, as modifications are made to films the silver level could change significantly. Film manufacturers should be consulted for up-to-date values.

Major sources of recoverable silver are: photoprocessing solutions, spent rinse water, scrap film, and scrap printing paper. The silver in these materials may exist as insoluble silver halide, soluble silver thiosulfate complex, silver ion, or elemental silver, depending on the type of process and the stage in the process where the silver is being recovered.

As much as 80 percent of the total silver processed for black-and-white positives and almost 100 percent of the silver processed in color work will end up in the fixer or bleach-fix solution. Silver is also present in the rinse water following the fixer or bleach-fix due to carry-over. The amount of silver in rinse water is only a small fraction of that in the fixer or bleach-fix solutions, but can be economically recovered when high volumes of rinse water are used. A variety of equipment types and sizes are available for silver recovery. Table 5 compares silver recovery methods. More detailed descriptions are given below.

Table 3. Silver Content of Films

Film Type	*Silver Content Troy ounces per sq. ft.*
Black/White Film	
Photofinishing	*0.0105*
Low Speed - ISO 32	*0.0073*
Medium Speed - ISO 125	*0.0104*
High Speed - ISO 320-400	*0.0156*
Ultra-fast - ISO 1250	*0.0264*
Black/White Prints	*0.0024*
Color Film	
Negative Process C-41	
Kodacolor II	*0.0169*
Vericolor II	*0.0208*
Kodacolor 400	*0.0278*
Kodacolor HR Disc Film	*0.0288*
Kodacolor VR Disc Film	*0.0263*
Kodacolor VR 200, 400, 1000	*0.0268*
Kodacolor VR 100	*0.0187*
Vericolor III	*0.0244*
Vericolor Slide/Print	*0.0088*
Reversal Process K-14	*0.0152*
Reversal Process E-6	
Low Speed	*0.0122*
Medium Speed	*0.0121*
High Speed	*0.0149*
Duplicating	*0.0121*
Duratrans Display 4022	*0.0020*
Motion Picture Film	
Ektachrome	*0.0095*
Kodachrome	*0.0142*
Negative Film	*0.0210*
Print	*0.0050*
Intermediate	*0.0081*
Internegative	*0.0096*
Reversal Films	
Kodachrome	*0.0137*
Ektachrome	*0.0162*
Print	*0.0098*
Intermediate	*0.0133*

NOTE: These figures can be used to estimate the silver content. Contact the film manufacturer for information or brands not on this table or for updates on the above information.

Reference: Calif. DHS 1989a.

Silver Recovery from Fixer Solution

The most common methods of silver recovery from the fixer and bleach fix processing solutions are metal replacement, electrolytic recovery, and chemical precipitation. Ion exchange and reverse osmosis are other methods that can be used. However, these are suitable only for dilute silver solutions such as wash water from a primary silver recovery unit

Table 4. Standard Film Roll Areas

Film Size	Area sq. ft.
110 12-exposure roll	0.078
110 20-exposure roll	0.113
110 24-exposure roll	0.131
126 12-exposure roll	0.177
126 20-exposure roll	0.272
126 24-exposure roll	0.319
127 roll	0.305
135 12-exposure roll	0.268
135 20-exposure roll	0.382
135 24-exposure roll	0.440
135 36-exposure roll	0.619
120 roll (black/white)	0.538
120 roll (color)	0.547
620 roll (black/white)	0.522
620 roll (color)	0.530
220 roll	1.090
828 roll	0.163

Reference: Calif. DHS 1989a.

which has been mixed with wash waters. Some facilities use a primary silver recovery unit, which removes the bulk of silver, in combination with a "tailing" unit to treat the relatively low silver concentration effluents from a primary silver recovery system. Color developer effluent does not flow through a silver recovery unit because the silver content is very low and the high pH developer if mixed with other silver-bearing solutions, could reduce the efficiency of silver recovery and could result in ammonia generation.

A silver recovery system can be devoted to a single process line or can be used to remove silver from the combined fixer from several process lines in a plant. Multiple-stream systems are more typical in large facilities. Sometimes a separate fixer system is used for specialty processing to reduce the possibility of inter-process contamination, which can occur when desilvered fixer is recycled to the photo process.

Metallic Replacement

Metallic replacement occurs when an active solid metal, such as iron, contacts a solution containing dissolved ions of a less active metal, such as silver. The more active metal goes into solution as an ion, being replaced by an atom of the less active metal in the solid matrix. The dissolved silver, which is present in the form of a thiosulfate complex, reacts with solid metal.

Silver ions will displace many of the common metals from their solid state. Because of its economy and convenience, iron in the form of steel wool is used most often. Hypothetically, zinc and aluminum can also serve as replacement metals; however, both have drawbacks. Zinc is not used because of its relative toxicity and greater cost. Aluminum is not used because it simultaneously generates hydrogen gas, which can be an explosion and fire hazard if improperly handled.

Table 5. Comparison of Silver Recovery Methods

Method	Advantages	Disadvantages
Metallic Replacement	Low investment Low operating cost Simplest operation	High iron content of effluent Silver recovered as sludge High silver concentration in effluent unless two units are in series
Electrolytic Recovery	Recovers silver as pure metal High silver recovery	Potential for sulfide formation High silver concentration in effluent
Precipitation	Can attain 0.1 mg Ag^{+}/L Low investment	Complex operation Silver recovered as sludge Treated solution cannot be reused Potential H_2S release
Reverse Osmosis	Also recovers other chemicals Purified water is recyclable	Concentrate requires further processing High investment High operating cost
Ion Exchange	Can attain 0.1 -2.0 mg Ag^{+}/L Good for very low Ag limits	Only for dilute influent Complex operation High investment
Evaporation	Minimum aqueous effluent Water conservation	High energy requirement Silver recovered as a sludge Organic contaminant buildup Potential air emissions

Commercially-available units consist of a steel wool-filled plastic canister with appropriate connections. Typical practice is to feed waste fixer to a train of two canisters in series. The first canister removes the bulk of the silver, and the second polishes the effluent of the first. It also is a safety factor if the first unit is overloaded. When the first is exhausted, the second becomes the first, and fresh unit replaces the second. One supplier recommends changing when the silver in the effluent of the first cartridge reaches 25 percent of the influent concentration (Eastman Kodak 1980). Silver concentration in the effluent from a single canister averages 40 to 100 mg/L over the life of the system, versus a range of 0.1 to 50 mg/L when two canisters are used in series. Fixer desilvered by this process cannot be recycled, because of excessive iron concentration in the effluent (averaging 4,000 mg/L).

For the most effective operation, the pH of the solution passing through the metallic replacement unit should be between 4 and 6.5. The optimum is between 5 and 5.5. Below pH 4, the dissolution of the steel wool is too rapid. Above pH 6.5, the replacement reactions may be so slow that silver removal is incomplete. Thus, proper pH control is important to high silver recovery. A metal replacement canister should recover about 85 percent of the recoverable silver in the form of a sludge, which must be further processed to produce pure metallic silver (Calif. DHS 1989a).

Electrolytic Recovery

An electrolytic unit can be used for a primary or a tailing waste stream, and can be either batch or continuous. This silver recovery method applies a direct current across two electrodes in a silver-bearing solution. Metallic silver deposits on the cathode. Sulfite and thiosulfate are oxidized at the anode:

$$H_2O + SO_3^{-2} \longrightarrow SO_4^{-2} + 2e^- + 2H^+ \text{ (Anode)}$$

$$SO_3^{-2} + S_2O_3^{-2} \longrightarrow S_3O_6^{-2} + 2e^- \text{ (Anode)}$$

$$Ag^+ + e^- \longrightarrow Ag^0 \text{ (Cathode)}$$

Approximately 1 gram of sodium sulfite is oxidized for each gram of silver deposited. Considerable agitation and large plating surface areas can achieve good plating efficiency and silver up to 90-98 percent pure. Lower silver purity levels usually result from tailing unit applications because of the lower silver concentration in the influent solution. The cathodes are removed periodically, and the silver metal is stripped off. An electrolytic system should recover about 90 percent of the recoverable silver.

Care must be taken to control the current density in the cell because high density can cause "sulfiding." Sulfiding is the decomposition of thiosulfate into sulfide at the cathode, which contaminates the deposited silver and reduces recovery efficiency. The higher the silver concentration, the higher the current density can be without sulfiding. Therefore, as the silver is plated out of solution, the current density must be reduced.

Batch Electrolytic Recovery

In batch recovery, overflow fixer from one or more process lines is collected in a tank. When sufficient volume is reached, the waste fixer is pumped to an electrolytic cell for silver removal. The desilvered fixer can be discharged to a sewer, disposed of as solid waste, or reused. If reused, it is transferred to a mix tank where sodium thiosulfate is added to replenish its strength.

Primary batch system cells are usually designed to desilver the fixing batch at initial silver concentrations of about 5,000 mg/L. The silver concentration in the effluent is typically 200-500 mg/L. Effluent of 20-50 mg/L is possible with additional treatment time and careful current density control. An electrolytic tailing cell typically achieves the lower range because the process can be optimized for low initial silver concentrations.

Continuous Electrolytic Recovery

The volume of a continuous electrolytic unit must be large enough relative to the incoming flow volume to ensure adequate residence time of the fixer, so two or more units can be placed in series to achieve this. The continuous flow of incoming fixer supplies a constant quantity of silver for electrolytic recovery. As a result, the units can be operated at a relatively stable current density. Such systems can be automatic. Some units can sense silver concentration in solution and adjust current densities. Usually, continuous flow units discharge desilvered fixer directly to the sewer.

Recirculating Electrolytic Recovery

Silver can also be removed from an in-use fixer solution at approximately the same rate it is added by film processing, using a continuously recirculating system. The recovery cell is connected "in-line" as part of the recirculation system. This continuous removal technique has the particular advantage of maintaining a relatively low silver concentration in the fixer processing solution, which minimizes the amount of silver carried out into the wash tank. The silver concentration in the fixer can be maintained in the range of 500 to 1,000 mg/L without forming sulfide.

A recirculating silver recovery unit receives a small continuous stream of fixer from an in-use process tank, removes the silver, then returns the desilvered fixer to the photoprocessor. Each photoprocessor requires a separate unit. Systems are available for treating all types of non-bleach fixers that have circulation pumps. Once installed, the unit is fully automatic, turning itself on by sensing the flow of fixer through the electrolytic cells. The cells themselves contain no moving parts, and the silver is harvested every two to three months.

Desilvered fixer solution can be reused, whether from an "in-line" continuous system or from batch. This requires adequate monitoring and process control to maintain composition and protect quality. Some manufacturers have special electrolytic fixers for this application. Parameters (pH, silver, and sulfate concentrations) should be monitored to maintain the physical and chemical properties of the fixer solution, usually through the addition of make-up chemicals.

Chemical Precipitation

Chemical precipitation is the oldest and cheapest method for recovery of silver. It is widely used by manufacturers of photographic supplies but usually not by photoprocessors. The two primary disadvantages are that extremely toxic hydrogen sulfide gas (H_2S) can be evolved, and that the resulting sludge may have to be managed as a hazardous waste. A third disadvantage is that recovery of silver from the sludge is more difficult than with other methods.

Sodium sulfide causes silver sulfide to precipitate readily from waste fixer solutions.

$$2Ag^+ + S^{-2} \longrightarrow Ag_2S$$

Silver sulfide has a solubility product of 10^{-50}, making it one of the most insoluble substances known. Precipitation must be carried out in alkaline media to avoid the generation of H_2S. Silver sulfide tends to form colloidal suspensions. Its very small particle size makes filtration difficult, and the filter cake generated is extremely dense. However, diatomaceous earth filter aid can be used to improve filtration. About three grams filter aid are required for each gram of silver, if a conventional plate-and-frame filter press is used (Calif. DHS 1989a).

Sodium borohydride ($NaBH_4$) is also an effective precipitant for silver:

$$NaBH_4 \longrightarrow Na^+ + BH_4$$

$$BH_4^- + 2H_2O + 8Ag^+ \longrightarrow 8Ag^0 + 8H^+ + BO_2^-$$

The borohydride method requires significantly more than the stoichiometric quantity to complete the reaction, while sodium sulfide precipitation requires use of very little excess chemicals. Borohydride also reduces many other metals such as cadmium, lead, and mercury (Cook and Lander 1979). The major difference between the two processes is the resulting silver quality. Sodium borohydride produces elemental silver of 96 to 98 percent purity. Either method can reduce silver concentrations to 0.1 mg/L in the fixer waste water.

The process mixes the precipitation agent with the silver-bearing waste water in a batch reaction tank equipped with automatic pH control. When sodium sulfide is used, the pH must be maintained above 7 to avoid releasing H_2S. The optimum pH range for sodium borohydride precipitation is 5.5 to 6.5 (Cook and Lander 1979). Solid particles having a size of 1 to 2 microns are formed, and are allowed to settle before filtering. Usually solutions reacted with either sodium sulfide or sodium borohydride are not reused in the photographic process

Silver Recovery From Rinse Water

Even with an efficient fixer solution silver recovery system and an effective squeegee on the fixer tank, up to 10 percent of the recoverable silver is lost by carry-over into the rinse tank. The silver concentration in the spent rinse water is typically in the range of 1 to 50 mg/L, too low for economical recovery with electrolytic or metallic replacement methods. In addition, the iron by-product from metallic replacement precludes reuse of the rinse water, although some photoprocessors use metallic replacement to meet municipal sewer effluent limits. Precipitation is uneconomical for rinse water (Calif. DHS 1989a).

Two methods are currently being used for effective recovery of silver from rinse water: resin ion exchange and reverse osmosis (RO). A third method, called "low flow prewash," has been used in a few locations in the United States.

Ion Exchange

Ion exchange is the reversible exchange of ions between a solid resin and a liquid. A variety of weak and strong anionic resins are effective in silver recovery. Using chloride as the mobile ion, the following represents the reaction:

$$\text{(Resin)-Cl} + \underset{\text{(in solution)}}{AgS_2O_3^-} \longrightarrow \text{(Resin)-}AgS_2O_3 + \underset{\text{(in solution)}}{Cl^-}$$

The silver-thiosulfate complex has a high affinity for the resin, making it difficult to reclaim the silver and regenerate the resin. Other problems include plugging of the resin by suspended matter, such as gelatin, but these have also been solved by improved equipment design and operational procedures. Some ion exchange units produce effluents with silver concentrations as low as 0.1 ppm, recovering as much as 98 percent of the silver (Eastman Kodak 1990). High-capacity units can process as much as 500 gallons per hour (Calif. DHS 1989b).

Reverse Osmosis

In reverse osmosis (RO) techniques, the waste water stream flows under pressure over the surface of a selectively permeable membrane. Water molecules pass through the membrane and other constituents are left behind. The extent of separation is determined by membrane surface chemistry and pore size, fluid pressure, and waste water characteristics. The RO unit has one inlet to receive the waste stream, and two discharge outlets. Purified water (permeate) exits from one outlet, and concentrated waste water exits from the other. This process reportedly can recover 90 percent of the silver thiosulfate (Eastman Kodak 1990). Silver can be recovered from the resulting concentrate by conventional silver recovery methods. The waste water must be pumped to a high pressure (about 600 psig) before feeding the RO unit, which may incur high energy and maintenance costs. Operating problems include fouling of the membrane and biological growth. Proper maintenance and control can alleviate these problems. One plant reported membrane fouling, which required frequent membrane replacement at high cost. The problem was solved by installing a sandbed filter upstream of the RO unit (Calif. DHS 1989a). RO requires more capital investment than most other silver recovery methods, discouraging its use in photoprocessing (Eastman Kodak 1990).

Low Flow Prewash

Low flow prewash involves segmenting the after-fix wash tank to perform the washing in two stages, with separate rinse water make-up and overflow. It does the after-fix washing in two stages. Most of the silver carry-over is washed off in the low volume, after-fix prewash tank. The system lessens dilution of the silver carry-over, but means that concentrations of fixer, silver, and other chemicals reach high levels in the prewash tank under steady-state conditions. One problem is that the work being processed may receive additional fix time and exposure to concentrated contaminants while immersed in the prewash. Some investigators fear that this may harm the quality of the processed material. Dye stability tests on color paper processed using the prewash system showed an increase in yellow stain six months after processing. Another problem is increased maintenance of the wash tank because of biological growth, although this can be controlled with biocides (Calif. DHS 1989a).

Silver Recovery from Scrap

Scrap film and paper result from trimmings, test strips, and leaders. The silver may be present in the form of silver salts or elemental silver from fogged or developed material. The processing of solid materials is more cumbersome than for solutions, but there are a number of silver recovery companies in business that will buy solid scrap. If necessary, the silver in scrap film and paper can be removed in the photo lab by treating the material with a sodium hypochlorite solution to oxidize elemental silver, assuring that all silver is in the form of salts that can be removed by fixing. Some photo labs collect fixer overflow in a container and add unprocessed scrap film or paper as it is generated. Once dissolved in the fixer, the silver can be recovered through the same silver recovery processes used by the lab for the fixer solutions from the photoprocessors. This approach can increase the amount of silver recovered on site, but can also be a bit messy. Digested film or paper can be difficult to handle and may even go sour, if left in the container long enough to be attacked by bacteria (Calif. DHS 1989a).

Processed or unprocessed film can be soaked in an agitated, hot solution of sodium hydroxide to remove the emulsion. The silver can then be separated from the solution by settling, centrifuging or filtering (Eastman Kodak 1980b). Some film base can be sold as scrap polymer after the silver-bearing emulsion has been removed, so segregating film by type of base is recommended.

Color Developer Reuse

Color developers which can be regenerated are available, allowing the photoprocessor to reduce replenisher purchases about 50 percent. One regeneration process requires the addition of an ion-exchange unit to remove the excess development by-products from the developer overflow. Another process accomplishes the same objective without ion exchange, using a different developer solution (Eastman Kodak 1989b).

Ferricyanide Recovery

Ferricyanide bleaches reduce to ferrocyanide during the bleach process. The spent ferrocyanide can be regenerated either electrolytically or chemically. Chemical methods employ either ozone or persulfate. Regenerated ferricyanide can be re-used in photoprocessing.

Electrolytic Regeneration

Spent bleach is fed to an electrolytic cell, where the following reactions occur (Eastman Kodak 1990):

Anode:

Primary: $2Fe(CN)_6^{-4} \longrightarrow 2Fe(CN)_6^{-3} + 2e^-$

Secondary: $4OH^- \longrightarrow O_2 + H_2 + 2OH^- + 2e^-$

Cathode:

Primary: $2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$

Secondary: $Fe(CN)_6^{-3} + e^- \longrightarrow Fe(CN)_6^{-4}$

The evolution of hydrogen gas presents a potential safety hazard.

Persulfate Regeneration

This method is relatively inexpensive and safe, since it does not liberate any hazardous gases. The reaction is:

$$2Fe(CN)_6^{-4} + S_2O_8^{-2} \longrightarrow 2Fe(CN)_6^{-3} + 2SO_4^{-2}$$

The major disadvantage is that gradual accumulation of sulfate salt reduces bleaching efficiency (Eastman Kodak 1990).

Ozone Regeneration

Ozone reacts with ferrocyanide to form ferricyanide as follows:

$$2Fe(CN)_6^{-4} + O_3 + H_2O \longrightarrow 2Fe(CN)_6^{-3} + 2OH^- + O_2$$

Hydrobromic acid is also added to control pH and to supply the bromide ion needed for the bleach process. The major advantage of this process is that there is no salt buildup. Disadvantages include high initial cost for the ozone generator and potential safety problems, since ozone is corrosive, unstable, and high reactive. Because of these disadvantages, this process is likely to be used only by large labs (Eastman Kodak 1990).

Ion Exchange

Bleach water containing dilute concentrations of hexacyanoferrates (either ferricyanide or ferrocyanide) can be passed through a column containing a weak base anion exchange resin, which removes the hexacyanoferrate. The resins then regenerated with sodium hydroxide, and the recovered hexacyanoferrate reacted with ozone or persulfate to recover ferricyanide as shown above. Treated effluent from this process can contain as little as 0.075 mg/L (75 parts per billion) hexacyanoferrate (Eastman Kodak 1990).

Reverse Osmosis

Reverse osmosis can remove up to 95 percent of the salts from fixer solutions, including nearly all of the hexacyanoferrates. The capital investment is relatively high, which has limited applicability of this process in photoprocessing (Eastman Kodak 1990).

Precipitation

Fixer overflow can be treated with ferrous sulfate and a flocculant to produce ferrous ferrocyanide. Then either sodium or potassium hydroxide is added to make the ferrocyanide, which can be reoxidized with one of the bleach regeneration techniques. The resulting ferricyanide can be reused as bleach replenisher.

Another method uses calcium chloride to precipitate the salt $Ca(NH_4)_2Fe(CN)_6$. This method can reduce ferrocyanide concentration of some color-reversal fixers to less than 1 g/L (Eastman Kodak 1990).

Water Conservation

Water conservation is especially important in certain parts of the United States where either (a) fresh water is in short supply or (b) local regulations severely limit or prohibit discharge of photoprocessing effluents to the sewer system. Some operators simply shut off the rinse water except when film is moving through the processor. However, certain processors require a continuous water flow to maintain temperature control. Many locales have established concentration-based limits on aqueous effluents. Photoprocessors must check the local requirements to be sure that reducing water without proportionately reducing all other contaminants will not violate the concentration limit.

Rinse Water Recycling

To maintain product quality, many photoprocessing operations use continuous rinse water flows. The result is rinse water waste streams usually are the highest volumes of waste from photoprocessors. This effluent consists primarily of water with low concentrations of chemicals from the carry-over of the processing solutions. Commercial rinse water recycling systems are available for photoprocessing operations. Spent rinse water can be treated to restore purity and recycled for rinsing. A small portion of incoming clean water is added to the recycled water stream, and an equivalent overflow goes to the sewer drain after the fixer wash. A single recycling system can serve several photoprocessor units.

Countercurrent Rinsing

Continuous photoprocessing trains may employ a series of rinse steps, designed so that water flows countercurrent to the process. Thus, fresh water is fed to the final stage. Overflow water then goes to the next stage upstream. Of course, the rinse water becomes more contaminated in each succeeding stage. Thus, it may be economical to use squeegees to minimize carryover of contaminants into each rinse stage, and a squeegee between the processing solution and the first wash stage is recommended. Otherwise, efficiency will be impaired and product quality will degrade.

Plumbingless Minilabs

Plumbingless minilabs use a proprietary chemical stabilizer in place of wash water. While conventional minilabs discharge 20 to 25 gallons of effluent per roll of film processed, this type of lab discharges less than 0.1 gallon of effluent per roll. Although the volume of effluent is greatly reduced, the concentrations of contaminants are much higher than for conventional minilabs. Wherever there are concentration limits on sewer discharges, potential users should review this point with local authorities if silver can be recovered from this effluent using either the metallic replacement or electrolytic processes described above (Eastman Kodak 1986).

Evaporation

Another option in managing waste photographic solutions is evaporation, in which the waste waters are collected and heated to evaporate all liquids. This is often done under vacuum to reduce the boiling temperature. The resulting sludge is collected in filter bags, which can be sent to a silver reclaimer for recovery. Evaporation can accommodate operations that do not have access to sewer connections or waste water discharge. If the water vapor is condensed and recycled, instead of being vented to the atmosphere, then this can be considered a source reduction technique.

One manufacturer has an automatic recirculating system in which aqueous effluent is continuously introduced into the evaporation chamber. The water is vaporized, then condensed and recycled to a rinse water holding tank. As the water evaporates, the solids are collected in one of two 5-micron filter bags. When the unit senses that the filter bag is full, it switches the flow to the other filter bag, and alerts the operator to remove the filled bag.

The advantage of this approach is it achieves "zero" water discharge. Virtually all of the silver in the waste solutions is captured with the solids. There are several disadvantages, however. One is that volatile organics in the waste solution may be evaporated as well, creating an air pollution problem. One evaporation unit has a charcoal air filter to capture these organics. A second disadvantage is that any organics which condense with the water will be recycled also, causing a potential buildup of their concentrations in the process. Finally, the cost of energy to evaporate water is likely to be high (Calif. DHS 1989a).

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Section 4
Waste Minimization Assessment Worksheets

The worksheets provided in this section are intended to assist photoprocessors in systematically evaluating waste generating processes and in identifying waste minimization opportunities. These worksheets include only the waste minimization assessment phase of the procedure described in the *Waste Minimization Opportunity Assessments Manual.* A comprehensive waste minimization assessment includes a planning and organizational step, an assessment step that includes gathering background data and information, a feasibility study on specific waste minimization options, and an implementation phase. For a full description of waste minimization assessment procedures, please refer to the manual. Table 6 lists the worksheets included in this section. After completing the worksheets, the assessment team should evaluate the applicable waste minimization options and develop an implementation plan.

Table 6. List of Waste Minimization Assessment Worksheets

Number	Title	Description
1.	Waste Minimization Status	Questionnaire on current status of waste minimization
2a.	Waste Miminization: Photoprocessor Operations	Questionnaire on operating procedures, Part I
2b.	Waste Minimization: Photoprocessor Operations	Questionnaire on operating procedures, Part II
3.	Option Generation: Photoprocessor Operations	
4.	Waste Minimization: Silver Recovery	Questionnaire on silver recovery
5.	Waste Minimization: Silver Recovery	Questionnaire on recovery methods
6.	Waste Minimization: Black and White Prints	Calculation form
7.	Waste Minimization: Color Prints	Calculation form
8.	Waste Miminization: Potentially Recoverable Silver	Calculation form
9.	Waste Sources	Relative importance of sources
10.	Waste Minimization: Material Handling	Questionnaire on material handling
11.	Waste Minimization: Material Handling	Questionnaire on procedures for drums, containers and packages
12.	Waste Minimization: Material Handling	Questionnaire on procedures for bulk liquids
13.	Option Generation: Material Handling	Waste minimization options for material handling operations

Firm ______ Site ______ Date ______	**Waste Minimization Assessment** Proj. No. ______	Prepared By ______ Checked By ______ Sheet ___ of ___ Page ___ of ___

WORKSHEET

1

WASTE MINIMIZATION:
Waste Minimization Status

Does this photoprocess laboratory have a formal waste minimization program? ❑ Yes ❑ No

If yes, who is responsible for overseeing the program? ______

Describe goals of the program and results: ______

______

Has a waste minimization assessment been performed previously at this laboratory? If so, describe results:

______

______

______

Have waste minimization techniques and options been discussed with:

Chemical suppliers?	❑ Yes	❑ No
Equipment vendors?	❑ Yes	❑ No
Regulatory agencies?	❑ Yes	❑ No

If so, describe results: ______

______

______

Does this laboratory have emission or waste disposal problems now?

Aqueous effluent	❑ Yes	❑ No
Air emissions	❑ Yes	❑ No
Solid waste	❑ Yes	❑ No

If the answer is YES, describe the problem(s): ______

______

______

Do you perform material balances routinely? ❑ Yes ❑ No

photows1.pm3

Firm ______ Site ______ Date ______	**Waste Minimization Assessment** Proj. No. ______	Prepared By ______ Checked By ______ Sheet ___ of ___ Page ___ of ___

WORKSHEET

2a

WASTE MINIMIZATION:
Photoprocessor Operations

Are formalized operating procedures used to control your photoprocessing operations? ☐ Yes ☐ No

If your answer is **YES**,

- Are these procedures in writing? ☐ Yes ☐ No
- Are these procedures available at each photoprocessing work area? ☐ Yes ☐ No
- Do the procedures include replenishment rates, wash water flow rates, and the use of test strips? ☐ Yes ☐ No
- Do the procedures include operation and maintenance of silver recovery equipment? ☐ Yes ☐ No

Are your photoprocessors inspected regularly? ☐ Yes ☐ No

If your answer is **YES**, do the inspections include:

- Equipment leaks? ☐ Yes ☐ No
- Replenishment rates and wash water flow settings? ☐ Yes ☐ No
- Chemical and washwater flows shut off when processor is not being used? ☐ Yes ☐ No
- Covers on photoprocessing chemicals containers when not in use? ☐ Yes ☐ No

Have you installed squeegees to minimize carryover of one chemical solution to another and from the fixer solution into the wash water? ☐ Yes ☐ No

photows2.pm3

Firm ______ Site ______ Date ______	**Waste Minimization Assessment** Proj. No. ______	Prepared By ______ Checked By ______ Sheet ___ of ___ Page ___ of ___

WORKSHEET

2b

WASTE MINIMIZATION:

Photoprocessor Operations

How are chemical replenishment rates set?

Use test strips*	❑	Operator experience	❑
Photoprocessor instructions	❑	Other	❑
Chemical supplier recommendations	❑		

When are batch chemical solutions discarded?

When product quality degrades	❑	After a pre-set time (e.g. weekly)	❑
When production run is finished	❑		
Other	❑		

How are rinse water rates set?

Use test strips*	❑	Operator experience	❑
Photoprocessor instructions	❑	Other	❑
Chemical supplier recommendations	❑		

How is rinse water used?

Once-through	❑	Still rinse	❑
Countercurrent	❑	Flowing rinse	❑
Recycled through clean-up system	❑		

Are any chemicals recovered and reused? ______________________________

____

If so, describe which ones and how: ______________________________

____

____

____

____

*Using test strips will minimize unnecessary additions and consequent discharges.

photows2.pm3

Firm ____ Site ____ Date ____	Waste Minimization Assessment Proj. No. ____	Prepared By ____ Checked By ____ Sheet ___ of ___ Page ___ of ___

WORKSHEET
3

OPTION GENERATION:
Photoprocessor Operations

Meeting format (e.g., brainstorming, nominal group technique) ____

Meeting Coordinator ____

Meeting Participants ____

Suggested Waste Minimization Options	Currently Done Y/N?	Rational/Remarks on Option
Increase Size of Production Run		
Perform Material Balance		
Keep Records of Waste Sources & Disposition		
Waste/Materials Documentation		
Provide Operating Manuals/Instructions		
Employee Training		
Increased Supervision		
Provide Employee Incentives		
Encourage Dry Cleanup		
Increase Plant Sanitation		
Establish Waste Minimization Policy		
Set Goals for Source Reduction		
Set Goals for Reduction		
Set Goals for Recycling		
Conduct Annual Assessments		
Use Test Strips		
Recover Silver from Effluents		
Regenerate Bleach or Bleach-Fix		

photows3.pm3

Firm ______ Site ______ Date ______	Waste Minimization Assessment Proj. No. ______	Prepared By ______ Checked By ______ Sheet ___ of ___ Page ___ of ___

WORKSHEET
4

WASTE MINIMIZATION: Silver Recovery

Has the quantity of silver processed been determined? ☐ Yes ☐ No

If no, estimate the amount based on film processed using worksheets 6, 7, and 8.

Enter quantity processed ______ Troy oz./mo.

Is silver now recovered from:

Developer solutions	☐ Yes ☐ No
Fixer solutions	☐ Yes ☐ No
Bleach or bleach-fix solutions	☐ Yes ☐ No
Rinsewater	☐ Yes ☐ No
Combined aqueous effluents	☐ Yes ☐ No
Silver-bearing solids (e.g. paper, film)	☐ Yes ☐ No

Quantity of silver recovered ______ Troy oz./mo.

Quantity of silver potentially recoverable ______ Troy oz./mo.

Which silver recovery processes are used? On which streams?

Metal replacement (one cartridge) ______
Metal replacement (series cartridge) ______
Electrolytic ______
Recirculating electrolytic ______
Batch electrolytic ______
Precipitation ______
Ion exchange ______
Hybrid (two or more processes) ______

photows4.pm3

Firm ____________ Site ____________ Date ____________	Waste Minimization Assessment Proj. No. ____________	Prepared By ____________ Checked By ____________ Sheet ___ of ___ Page ___ of ___

WORKSHEET
5

WASTE MINIMIZATION:
Silver Recovery

METALLIC REPLACEMENT

Do you use silver test strips on the discharge water to make sure that the canister is operating efficiently? ☐ Yes ☐ No

Do you change the canister immediately whenever the test strip shows silver in the discharge? ☐ Yes ☐ No

Do you inspect the canister system regularly for the following:

- Leaks from the hose connection? ☐ Yes ☐ No
- Plugging and channeling? ☐ Yes ☐ No

Do you make sure that your canister has a constant flow of solution running through it (rather than intermittent dripping during operation)? ☐ Yes ☐ No

ELECTROLYTIC RECOVERY

Do you check the current on the electrolytic unit(s) regularly (at least daily) to ensure it is within the range specified by the manufacturer? ☐ Yes ☐ No

Do you check the unit(s) to ensure that agitation is adequate (the cathode or anode is rotating, the solution pumps are working)? ☐ Yes ☐ No

Is a filter used to remove dirt and other particles from the fixer solution before it enters the electrolytic unit? ☐ Yes ☐ No

Do you use silver test strips on the discharge water daily to make sure that the electrolytic unit(s) is operating efficiently? ☐ Yes ☐ No

photows5.pm3

Firm ____ Site ____ Date ____	Waste Minimization Assessment Proj. No. ____	Prepared By ____ Checked By ____ Sheet ___ of ___ Page ___ of ___

WORKSHEET **6**

WASTE MINIMIZATION: Black & White Prints

BLACK & WHITE PRINTS

Use this worksheet to estimate the area processed each month.

Size In Inches	# Prints Per Month		Sq. Ft. Per Print		Sq. Ft. Per Month
2 1/4 x 3 1/4	____	x	0.0508	=	____
2 1/2 x 3 1/2	____	x	0.0608	=	____
3 1/4 x 4 1/4	____	x	0.0959	=	____
3 1/2 x 3 1/2	____	x	0.0850	=	____
3 1/2 x 4 1/2	____	x	0.1094	=	____
[3 1/2 x 5]	____	x	0.1215	=	____
4 x 5	____	x	0.139	=	____
4 1/2 x 10	____	x	0.313	=	____
4 1/2 x 17	____	x	0.531	=	____
[5 x 7]	____	x	0.243	=	____
7 x 17	____	x	0.826	=	____
[8 x 10]	____	x	0.556	=	____
10 x 12	____	x	0.833	=	____
[11 x 14]	____	x	1.070	=	____
14 x 17	____	x	1.650	=	____
[16 x 20]	____	x	2.220	=	____
18 x 24	____	x	3.000	=	____
[20 x 24]	____	x	3.330	=	____
30 x 40	____	x	8.330	=	____
34 x 44	____	x	10.40	=	____
SUBTOTAL					____

NOTE:
Standard sizes are noted by boxes, i.e., [3 1/2 x 5]

photows6.pm3

Firm ______	Waste Minimization Assessment	Prepared By ______
Site ______		Checked By ______
Date ______	Proj. No. ______	Sheet ___ of ___ Page ___ of ___

WORKSHEET

7

WASTE MINIMIZATION:

Color Prints

COLOR PRINTS

Use this worksheet to estimate the area processed each month.

Size In Inches	# Prints Per Month		Sq. Ft. Per Print		Sq. Ft. Per Month
2 1/4 x 3 1/4	______	x	0.0508	=	______
2 1/2 x 3 1/2	______	x	0.0608	=	______
3 1/4 x 4 1/4	______	x	0.0959	=	______
3 1/2 x 3 1/2	______	x	0.0850	=	______
3 1/2 x 4 1/2	______	x	0.1094	=	______
[3 1/2 x 5]	______	x	0.1215	=	______
4 x 5	______	x	0.139	=	______
4 1/2 x 10	______	x	0.313	=	______
4 1/2 x 17	______	x	0.531	=	______
[5 x 7]	______	x	0.243	=	______
7 x 17	______	x	0.826	=	______
[8 x 10]	______	x	0.556	=	______
10 x 12	______	x	0.833	=	______
[11 x 14]	______	x	1.070	=	______
14 x 17	______	x	1.650	=	______
[16 x 20]	______	x	2.220	=	______
18 x 24	______	x	3.000	=	______
[20 x 24]	______	x	3.330	=	______
30 x 40	______	x	8.330	=	______
34 x 44	______	x	10.40	=	______
SUBTOTAL					______

NOTE:

Standard sizes are noted by boxes, i.e., [3 1/2 x 5]

photows7.pm3

Firm ____	Waste Minimization Assessment	Prepared By ____
Site ____		Checked By ____
Date ____	Proj. No. ____	Sheet ___ of ___ Page ___ of ___

WORKSHEET
8

WASTE MINIMIZATION:
Recoverable Silver

Source	Sq. Ft.1 per mo.		Troy Oz.2 per sq. ft.		Processed Troy oz./mo.		Recovery Factor		Potentially Recoverable Troy oz./mo.
Black & White Film	____	x	____	=	____	x	0.8	=	____
Color Film	____	x	____	=	____	x	1.0	=	____
Black & White Prints	____	x	____	=	____	x	0.5	=	____
Color Prints	____	x	____	=	____	x	1.0	=	____
Motion Picture Film	____	x	____	=	____	x		=	____
Other	____	x	____	=	____	x		=	____
TOTAL SILVER					====				====

Notes:
[1]See Worksheets 6 and 7 for film roll area calculation.
[2]See Table 3 or consult your supplier for silver content.

photows8.pm3

Firm ____________ Site ____________ Date ____________	**Waste Minimization Assessment** Proj. No. ____________	Prepared By ____________ Checked By ____________ Sheet ___ of ___ Page ___ of ___

WORKSHEET
9

WASTE SOURCES

Waste Source: Material Handling	Significance at Plant		
	Low	Medium	High
Off-spec materials			
Obsolete materials			
Spills & leaks (liquids)			
Spills (powders)			
Empty container cleaning			
Container disposal (metal)			
Container disposal (paper)			
Container disposal (plastic)			
Pipeline/tank drainage			
Evaporative losses			
Other			
Waste Source: Process Operations			
Tank cleaning			
Container cleaning			
Process effluent			
Spent rinsewater			
Filling equipment cleaning			
Film reels, canisters, spools			
Other			

photowe9.pm3

Firm ____________ Site ____________ Date ____________	Waste Minimization Assessment Proj. No. ____________	Prepared By ____________ Checked By ____________ Sheet ___ of ___ Page ___ of ___

WORKSHEET
10

WASTE MINIMIZATION:
Material Handling

A. GENERAL HANDLING TECHNIQUES

Are all input materials tested for quality before being accepted from suppliers? ☐ Yes ☐ No

Describe safeguards to prevent the use of materials that may generate off-spec product: ____________

____

____

____

Is obsolete material returned to the supplier? ☐ Yes ☐ No
Is inventory used in first-in, first-out order? ☐ Yes ☐ No
Is the inventory system computerized? ☐ Yes ☐ No
Does the current inventory control system adequately prevent waste generation? ☐ Yes ☐ No

What information does the system track? ____________

____

____

Is there a formal personnel training program on material handling, spill prevention, proper storage techniques, and waste handling procedures? ☐ Yes ☐ No

Does the program include information on the safe handling of the types of drums, containers, and packages received? ☐ Yes ☐ No

Are written procedures available and easily accessible? ☐ Yes ☐ No

How often is training given and by whom? ____________

____

____

What spill containment methods are used? ____________

____

____

____

photows10.pm3

Firm ______ Site ______ Date ______	Waste Minimization Assessment Proj. No. ______	Prepared By ______ Checked By ______ Sheet ___ of ___ Page ___ of ___

WORKSHEET **11**

WASTE MINIMIZATION:
Material Handling

B DRUMS, CONTAINERS, AND PACKAGES

Are drums, packages, and containers inspected for damage before being accepted? ☐ Yes ☐ No

Are employees trained in ways to safely handle the types of drums & packages received? ☐ Yes ☐ No

Are they properly trained in handling of spilled raw materials? ☐ Yes ☐ No

Are stored items protected from damage, contamination or exposure to heat, light and air? ☐ Yes ☐ No

Describe handling procedures for damaged items: ______________________________

____

____

____

Does the layout of the facility result in heavy traffic through the raw material storage area? ☐ Yes ☐ No
(Heavy traffic increases the potential for contaminating raw materials with dirt or dust and for causing spilled materials to become dispersed throughout the facility.)

Can traffic through the storage area be reduced? ☐ Yes ☐ No

To reduce the generation of empty containers and liquid wastes due to their cleaning, has the facility attempted to:

- Purchase pre-mixed solutions to minimize measuring, mixing, and handling? ☐ Yes ☐ No
- Purchase solutions in recyclable containers? ☐ Yes ☐ No
- Other approaches (Describe ______________________________) ☐ Yes ☐ No

Discuss the results of these attempts: ______________________________

____

____

____

Are all empty bags, packages, and containers that contained hazardous materials segregated from those that contained non-hazardous wastes? Describe method currently used to dispose of hazardous waste:

____

____

____

____

photows11.pm3

Firm ______	Waste Minimization Assessment	Prepared By ______
Site ______		Checked By ______
Date ______	Proj. No. ______	Sheet ___ of ___ Page ___ of ___

WORKSHEET
12

WASTE MINIMIZATION:
Material Handling

C. BULK LIQUIDS HANDLING

What safeguards are in place to prevent spills and avoid ground contamination during the filling of storage tanks?

- High level shutdown/alarms ☐
- Secondary containment ☐
- Flow totalizers with cutoff ☐
- Other ☐

Describe the system: ______

Are air emissions from bulk chemical storage tanks controlled by means of:

- Conservation vents ☐
- Absorber/Condenser ☐
- Adsorber ☐
- Nitrogen blanketing ☐
- Other vapor loss control system ☐

Describe the system: ______

Are all storage tanks routinely monitored for leaks? If yes, describe procedure and monitoring frequency for aboveground/vaulted tanks: ______

Underground tanks: ______

How are the liquids in these tanks dispensed to the users? (i.e., in small containers or hard piped.) ______

Are pipes cleaned regularly? Also discuss the way pipes are cleaned and how the resulting waste is handled: ______

When a spill of liquid occurs what cleanup methods are employed (e.g., wet or dry)? Also discuss the way in which the resulting wastes are handled: ______

photows12.pm3

Firm ______ Site ______ Date ______	Waste Minimization Assessment Proj. No. ______	Prepared By ______ Checked By ______ Sheet ___ of ___ Page ___ of ___

WORKSHEET
13

WASTE MINIMIZATION:
Material Handling

Meeting Format (e.g., brainstorming, nominal group technique) ______

Meeting Coordinator ______

Meeting Participants ______

Suggested Waste Minimization Options	Currently Done Y/N	Rationale/Remarks on Option
A. GENERAL HANDLING TECHNIQUES		
Quality Control Check		
Return Obsolete Material to Supplier		
Minimize Inventory		
Computerize Inventory		
Formal Training		
Recycle Film Reels, Canisters, and Spools		
B. DRUMS, CONTAINERS, AND PACKAGES		
Raw Material Inspection		
Proper Storage/Handling		
Pre-mixed Solutions		
Recyclable Containers		
Bulk Delivery		
Waste Segregation		
C. BULK LIQUIDS HANDLING		
High Level Shutdown/Alarm		
Flow Totalizers with Cutoff		
Secondary Containment		
Air Emissions Control		
Leak Monitoring		
Spilled Material Reuse		
Cleanup Methods to Promote Recycling		

photows13.pm3

Appendix A
Photoprocessing Laboratory Assessments
Case Studies of Photoprocessors A, B, C and D

Case Studies of Photoprocessing Laboratories

In 1989, the California Department of Health Services (DHS) commissioned a waste minimization study of photoprocessing laboratories. The objectives of the waste minimization assessments were to:

- Gather site-specific information concerning the generation, handling, storage, treatment, and disposal of hazardous waste;
- Evaluate existing waste reduction practices;
- Develop recommendations for waste reduction through source control, treatment, and recycling techniques; and
- Assess costs and benefits of existing and recommended waste reduction techniques.

In addition, the results of the waste assessments were used to prepare waste minimization assessment worksheets to be completed by other photoprocessors in a self-assessment process.

The first step in conducting the assessments was selecting and contacting the photoprocessors to solicit voluntary participation in the study. Selection emphasized small businesses, which generally lack the financial and/or internal technical resources to perform a waste reduction assessment.

This Appendix presents both the results of the assessments of three photoprocessing labs (here identified as A, B, and C) and the potentially useful waste minimization options identified through the assessments. Also included are the practices already in use at the plants that have successfully reduced waste generation from past levels. The original assessments may be obtained from:

Mr. Benjamin Fries
California Department of Health Services
Alternative Technology Division
Toxic Substances Control Program
714/744 P Street
Sacramento, CA 94234-7320
(916) 324-1807

A fourth photoprocessor performed a self-assessment using the worksheets presented in Section 4 (Case D). This case was not part of the DHS study.

Photoprocessor A Assessment

Facility Description

Photoprocessor A operates 12 hours a day, five days a week. The staff consists of 25 people. Monthly photoprocessing volumes are listed below:

Black & White Film	500	rolls
Black & White Prints	347.5	sq.ft.
Color Negatives	2,400	rolls
Color Prints	25,135	sq.ft.
Color Slides	1,000	rolls
Color Prints from Slides	4,232	sq.ft.
Internegatives (Color)	139	sq.ft.
Internegatives (B&W)	278	sq.ft.

Inventory Management

The company uses a first-in/first-out policy to prevent chemicals from deteriorating in storage. It also has a computerized inventory tracking system which it uses to maintain a one-month inventory. As a result, waste from off-specification material which has exceeded its shelf life rarely occurs.

The storage areas are checked daily on an informal basis for spills or leaks. There is an informal training program to ensure proper storage and handling.

Waste Generation, Handling and Disposal

All aqueous waste discharges to a public sewer which carries the discharges to a Publicly-Owned Treatment Works (POTW). The laboratory has an electrolytic silver recovery unit to treat fixer solutions, followed by a canister-type silver recovery unit. These recovery units are serviced by an outside contractor. The photoprocessor relies on the contractor to check and maintain these units. Wash water streams do not flow through the silver recovery units. Fixer is not recycled.

Silver Recovery

Based on the monthly photoprocessing volumes listed above, Photoprocessor A estimates it handles the following quantities of silver:

Source	oz./mo
Black/White Film Processing	2.0
Black/White Print	0.9
Color Film Processing	33.2
Color Print Processing	75.4
Total Silver	111.5

Photoprocessor A estimates it presently recovers 96 ounces of silver per month or about 86 percent of the total. Unrecovered silver, 15.5 ounces per month, is assumed to be lost in wash water, which is not treated. Based on a silver price of $6.00 per Troy ounce, this loss amounts to $93 per month or $1,116 per year.

Aqueous Waste Minimization

This lab does not recycle either fixer or rinse water. Sewer charges average $58 per month and water bills average $118 per month. The assessment team estimated that a rinse water recycling system could save $106 per month.

Other Waste Minimization Practices

Photoprocessor A has not installed squeegees to minimize carryover of solutions, except where these were supplied as part of the original equipment. Management believes that additional squeegees may be impractical, since the facility uses a roller transport system. Both bulk and in-use chemical solutions are kept covered whenever possible. Chemical replenishment and wash water rates are determined by using test strips for continuous photoprocessing, and at the end of a production run for batch processing.

Recommendations

Photoprocessor A should take the following actions to minimize waste:

- Use test strips on its batch chemical solutions to determine when these should be discarded. Although the company did not provide cost data for photoprocessing chemicals, this is a low cost-option which the WMOA team believes could result in savings.
- Monitor its own silver recovery units to assure they are performing as efficiently as possible.
- Include replenishment rates, water flow rates, and test strips in its written operating procedures.
- Evaluate recycling rinse water, including recovering silver.
- Evaluate recycling fixer.

Photoprocessor B Assessment

Facility Description

Photoprocessor B has three employees and operates 8 hours a day, six days a week. Photoprocessing is almost entirely color negatives and color prints, since the company sends black-and-white film and color slides off-site for processing.

Estimated monthly production volumes are:

Color Negatives	20	rolls
Color Prints	5,500	sq.ft.
Duplicate Slides	10	rolls

Inventory Management

This company does not have a formal inventory management system, but waste from off-specification material which has exceeded its shelf life occurs infrequently. Inventory is used on a first-in, first-out basis. Stored material is checked daily for leaks or spills. There is no formal procedure for training.

Waste Generation, Handling, and Disposal

Waste bleach/fix solution is treated with an electrolytic silver recovery unit. The desilvered solution is then drummed and sent off-site to a commercial reclaimer. This waste amounts to about 1450 gallons per year, or about two drums a month, and costs $2,175 per year in disposal fees. Other aqueous wastes discharge to the public sewer, which carries the discharge to a Publicly-Owned Treatment Works (POTW).

Silver Recovery

This lab estimates that it handles 28 ounces of recoverable silver per month. At a price of $6.00 per Troy ounce, this quantity is worth $168 per month or $2016 per year. Although there is an electrolytic recovery unit for the bleach/fix solution, the lab does not record the amount or value of silver recovered.

Aqueous Waste Minimization

Neither fixer solution nor rinse water is recycled. Water and sewer costs are included in the building lease, so there is no estimate of potential savings for reducing water use.

Other Waste Minimization Practices

Photoprocessor B relies upon operator experience to set chemical replenishment rates and wash water flow rates to the continuous process. Batch chemical solutions are discarded at the end of a production run. No squeegees have been installed, and floating lids are used on chemical solutions.

Recommendations

The assessment team recommended that Photoprocessor B take the following actions:

- Use test strips to set chemical replenishment and wash water, flow rates on continuous processors and to determine when to discard batch chemical solutions.
- Establish procedures to routinely maintain and monitor performance of the electrolytic silver recovery unit.
- Evaluate installing a metallic replacement unit to recover silver from spent wash water.

Photoprocessor C Assessment

Facility Description

Photoprocessor C operates from 7:30 A.M. to 1 A.M. seven days a week. There are 45 production employees and 25 persons in sales and administration. Monthly processing volumes are estimated as:

Black & White Film	1,000 rolls
Black & White Prints	3,000 sq. ft.
Color Negative	4,000 rolls
Color Prints	50,000 sq. ft.
Color Prints from Slides	10,000 rolls

Inventory Management

The company performs an inventory twice a year, and tries to maintain a one-month stock of materials. Material usage depends largely on accessibility. There is no first-in/first-out usage policy, so material occasionally becomes waste because it has exceeded its shelf life.

Storage areas are checked daily for spills and leaks. The chemical storage area is diked, and absorbent pillows are available to contain spills. However, the company does not have a program to train personnel in handling and storing materials, nor are personnel trained in spill response procedures.

Waste Generation, Handling and Disposal

All aqueous wastes go to a public sewer and then to a Publicly-Owned Treatment Works (POTW). Approximately 9,200 gallons a year of spent bleach/fix solution is given to a contractor, who recovers the silver and disposes of the rest of the solution. The contractor handles all reports and manifests for hazardous waste handling and disposal. The company pays nothing for this service, but receives no credit for recovered silver.

Silver Recovery

Photoprocessor C estimates it handles the following quantities of silver:

Source	oz./mo
Black/White Film Processing	4.0
Black/White Prints Color	7.2
Film & Slides	47.2
Color Prints Processing	150.0
Total Silver	208.4

The company does not recover any silver on site. There is no estimate of the amount of silver discharged to the sewer. At a price of $6.00 per Troy ounce, quantity is worth $1,250 per month or $25,000 per year.

Aqueous Waste Minimization

Photoprocessor C does not recycle either fixer or rinse water. Sewer charges average $200 per month and the water bill averages $250 monthly. In addition, the company spends about $50 per month to treat its make-up water. The assessment team estimated that water recycling could potentially save $280 per month.

Other Waste Minimization Practices

Photoprocessor C sets chemical replenishment rates and wash water flow rates according to the manufacturer's operating instructions for continuous processing. Batch chemical solutions are discarded after a pre-determined time (e.g., daily or weekly). Fixed lids are used on chemical solution containers. Squeegees have not been installed, unless they were provided with the original equipment.

Recommendations

Photoprocessor C should take the following actions to minimize waste:

- Implement a first-in/first-out inventory procedure. This may require reorganizing the storage area to improve accessibility by the operators.
- Train operators in proper storage and handling proce dures and in spill response/cleanup procedures.
- Use test strips to set chemical replenishment and wash water flow rates on continuous processors and to determine when to discard batch chemical solutions.
- Evaluate installing both silver recovery and bleach/fix reuse.
- Evaluate installing a rinse water recycling system.

Photoprocessor D Assessment

Facility Description

The size of staff and number of hours per week were not identified for this establishment, whose primary activity is producing over 35,000 square feet of color prints per month. The lab is owned by a large corporation which has a policy of minimizing waste in its operations.

Inventory Management

The company uses a first-in/first-out policy and has a computerized inventory management system, which tracks the total amounts of materials used and the amount per order. There is a formal personnel training program given bi-annually by the Safety Committee and the Lead Technician which covers material handling, spill prevention, proper storage techniques, and waste handling procedures. Written procedures are available and accessible to all personnel.

Incoming materials are not tested for quality before the photoprocessor accepts them. However, damaged containers are not accepted, but are immediately returned to the supplier. All chemicals are liquids. Containers are rinsed with water, and the water is subsequently reused in the process. The containers are then cut, so they cannot be misused later.

Silver Recovery

The company uses both electrolytic and metallic replacement methods to recover silver from waste water. It estimated that it handles an average of 357.5 Troy ounces of silver per month but did not report the amount of silver recovered. Silver is not recovered from either developer solutions or solid wastes.

Aqueous Waste Minimization

Low-flow wash is used, and wash water flows are shut off when the processing system is not in use. Water used to rinse empty chemical containers is reused in the process.

Other Waste Minimization Practices

The company has installed wet floor sensors with an audible alarm, so that corrective action can be taken promptly in case of a leak or spill. Small spills are cleaned up with either sand, a mop, or a wet vacuum. Large spills are contained with dikes and cleaned up with a wet vacuum. Spilled chemicals are not reused because of potential contamination but are diluted with water and discharged to the sewer.

A chemical spill kit is located in the area where chemicals are mixed and stored. This includes personal protective gear (gloves, goggles, boots, and respirator) as well as dikes, sand, mops, and floor squeegees.

Squeegees have been installed to reduce carry over of process solutions.

Chemical replenishment and rinse water rates are set based on the use of test strips. Batch chemical solutions are discarded when product quality degrades.

Recommendations

The company plans to investigate using recyclable chemical containers.

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WORKSHEET 1

WASTE MINIMIZATION: Waste Minimization Status

Does this facility have a formal waste minimization program? [XX] Yes [ ] No

Who is responsible for overseeing the program? Operations Manager

Has a waste minimization assessment been performed previously at this facility? If so, describe results: No

Have waste minimization techniques and options been discussed with:

Chemical suppliers?	[X] Yes	[ ] No
Equipment vendors?	[X] Yes	[ ] No
Regulatory agencies?	[ ] Yes	[XX] No

If so, describe results: C-PAC suggestions on double tailing of electrolysised chemicals to reduce amount of silver in water being discharged into the sewer. Fuji/Hunt on bleach regeneration techniques.

Does the facility have emission or waste disposal problems now?

Aqueous effluent	[ ] Yes	[XX] No
Air emissions	[ ] Yes	[XX] No
Solid waste	[ ] Yes	[XX] No

If the answer is YES, describe the problem(s): ______

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WORKSHEET 2

WASTE MINIMIZATION: Photoprocessor Operations

Are formalized operating procedures used to control your photoprocessing operations?

☒ Yes ☐ No

If your answer is **YES**,

Are these procedures in writing? ☒ Yes ☐ No

Are these procedures available at each photoprocessing work area?

☒ Yes ☐ No

Do the procedures include replenishment rates, wash water flow rates, and the use of test strips?

☒ Yes ☐ No

Do the procedures include operation and maintenance of silver recovery equipment?

☒ Yes ☐ No

Are your photoprocessors inspected regularly? ☒ Yes ☐ No

If your answer is **YES**, do the inspections include:

Equipment leaks? ☒ Yes ☐ No

Replenishment rates and wash water flow settings? ☒ Yes ☐ No

Chemical and washwater flows shut off when processor is not being used? ☒ Yes ☐ No

Covers on photoprocessing chemicals containers when not in use? ☒ Yes ☐ No

Have you installed squeegees to minimize carryover of one chemical solution to another and from the fixer solution into the wash water? ☒ Yes ☐ No

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WORKSHEET

3

WASTE MINIMIZATION:

Photoprocessor Operations

How are chemical replenishment rates set?

- Use test strips* [X]
- Photoprocessor instructions [ ]
- Chemical supplier recommendations [ ]
- Operator experience [ ]
- Other [ ]

When are batch chemical solutions discarded?

- When product quality degrades [X]
- When production run is finished [ ]
- Other [ ]
- After a pre-set time (e.g. weekly) [ ]

How are rinse water rates set?

- Use test strips* [X]
- Photoprocessor instructions [ ]
- Chemical supplier recommendations [ ]
- Other experience [ ]
- Other [ ]

How is rinse water used?

- Once-through [ ]
- Countercurrent [ ]
- Recycled through clean-up system [ ]
- Still rinse [X]
- Flowing rinse [X]

Are any chemicals recovered and reused? No

______

If so, describe which ones and how: ______

______

______

______

______

*Using test strips will minimize unnecessary additions and consequent discharges.

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WORKSHEET **4**

WASTE MINIMIZATION: Silver Recovery

Has the quantity of silver processed been determined? ☐ Yes ☒ No

If no, estimate the amount based on film processed using worksheets 6, 7, and 8.

Enter quantity processed ______ Troy oz./mo.

Is silver now recovered from:

Developer solutions	☐ Yes	☒ No
Fixer solutions	☒ Yes	☐ No
Bleach or bleach-fix solutions	☒ Yes	☐ No
Rinsewater	☒ Yes	☐ No
Combined aqueous effluents	☒ Yes	☐ No
Silver-bearing solids (e.g. paper, film)	☐ Yes	☒ No

Quantity of silver recovered ______ Troy oz./mo.

Quantity of silver potentially recoverable ______ Troy oz./mo.

Which silver recovery processes are used? On which streams?

Metal replacement (one cartridge)	
Metal replacement (series cartridge)	X
Electrolytic	X
Recirculating electrolytic	
Batch electrolytic	
Precipitation	
Ion exchange	
Hybrid (two or more processes)	X All Bleach, Fix, Low Flo Wash

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WORKSHEET
5

WASTE MINIMIZATION:
Silver Recovery

METALLIC REPLACEMENT

Do you use silver test strips on the discharge water to make sure that the canister is operating efficiently? [XX] Yes [ ] No

Do you change the canister immediately whenever the test strip shows silver in the discharge? [XX] Yes [ ] No

Do you inspect the canister system regularly for the following:

- Leaks from the hose connection [XX] Yes [ ] No
- Plugging and channeling [XX] Yes [ ] No

Do you make sure that your canister has a constant flow of solution running through it (rather than intermittent dripping during operation)? [XX] Yes [ ] No

ELECTROLYTIC RECOVERY

Do you check the current on the electrolytic unit(s) regularly (at least daily) to ensure it is within the range specified by the manufacturer? [XX] Yes [ ] No

Do you check the unit(s) to ensure that agitation is adequate (the cathode or anode is rotating, the solution pumps are working)? [XX] Yes [ ] No

Is a filter used to remove dirt and other particles from the fixer solution before it enters the electrolytic unit? [XX] Yes [ ] No

Do you use silver test strips on the discharge water daily to make sure that the electrolytic unit(s) is operating efficiently? [XX] Yes [ ] No

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WORKSHEET
6

WASTE MINIMIZATION:
Black & White Prints

BLACK & WHITE PRINTS

Use this worksheet to estimate the amount of silver processed each month.

Size in inches	*# Prints Per Month*		*Sq. Ft. Per Print*		*Sq. Ft. Per Month*
	Not Applicable				Not Applicable
2 1/4 x 3 1/4	______	x	0.0508	=	______
2 1/2 x 3 1/2	______	x	0.0608	=	______
3 1/4 x 4 1/4	______	x	0.0959	=	______
3 1/2 x 3 1/2	______	x	0.0850	=	______
3 1/2 x 4 1/2	______	x	0.1094	=	______
[3 1/2 x 5]	______	x	0.1215	=	______
4 x 5	______	x	0.139	=	______
4 1/2 x 10	______	x	0.313	=	______
4 1/2 x 17	______	x	0.531	=	______
[5 x 7]	______	x	0.243	=	______
7 x 17	______	x	0.826	=	______
[8 x 10]	______	x	0.556	=	______
10 x 12	______	x	0.833	=	______
[11 x 14]	______	x	1.070	=	______
14 x 17	______	x	1.650	=	______
[16 x 20]	______	x	2.220	=	______
18 x 24	______	x	3.000	=	______
[20 x 24]	______	x	3.330	=	______
30 x 40	______	x	8.330	=	______
34 x 44	______	x	10.40	=	______
		TOTAL			

NOTE:
Standard sizes are noted by boxes, i.e., [3 1/2 x 5]

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WORKSHEET 7

WASTE MINIMIZATION:
Color Prints

COLOR PRINTS

Use this worksheet to estimate the amount of silver processed each month.

Size in inches	*# Prints Per Month*		*Sq. Ft. Per Print*		*Sq. Ft. Per Month*
2 1/4 x 3 1/4		x	0.0508	=	
2 1/2 x 3 1/2		x	0.0608	=	
3 1/4 x 4 1/4		x	0.0959	=	
3 1/2 x 3 1/2		x	0.0850	=	
3.1/2 x 4 1/2		x	0.1094	=	
[3 1/2 x 5]		x	0.1215	=	
4 x 5	162,000	x	0.139	=	22,518
4 1/2 x 10		x	0.313	=	
4 1/2 x 17		x	0.531	=	
[5 x 7]	21,600	x	0.243	=	5,249
7 x 17		x	0.826	=	
[8 x 10]	13,500	x	0.556	=	7,506
10 x 12		x	0.833	=	
[11 x 14]		x	1.070	=	
14 x 17		x	1.650	=	
[16 x 20]		x	2.220	=	
18 x 24		x	3.000	=	
[20 x 24]		x	3.330	=	
30 x 40		x	8.330	=	
34 x 44		x	10.40	=	
			TOTAL		35,273

NOTE:
Standard sizes are noted by boxes, i.e., [3 1/2 x 5]

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WORKSHEET **8**

WASTE MINIMIZATION: Recoverable Silver

Source	Processed Troy oz./mo.	Recovery Factor	Potentially Recoverable Troy oz./mo.
Black & White Film	N/A	0.8	
Color Film	2.5	1.0	2.5
Black & White Prints	N/A	0.5	
Color Prints	350	1.0	350
Motion Picture Film	N/A		
Other	---		
TOTAL	357.5		357.5

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WORKSHEET
9

WASTE SOURCES

Waste Source: Material Handling	Significance at Plant		
	Low	Medium	High
Off-spec materials	XX		
Obsolete materials	XX		
Spills & leaks (liquids)	XX		
Spills (powders)	XX		
Empty container cleaning	XX		
Container disposal (metal)	XX		
Container disposal (paper)		XX	
Container disposal (plastic)	XX		
Pipeline/tank drainage	XX		
Evaporative losses	XX		
Other			

Waste Source: Process Operations			
Tank cleaning	XX		
Container cleaning	XX		
Process effluent	XX		
Spent rinsewater	XX		
Filling equipment cleaning	XX		
Film reels, canisters, spools	XX		
Other			

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WORKSHEET **10**

WASTE MINIMIZATION: Material Handling

A. GENERAL HANDLING TECHNIQUES

Are all input materials tested for quality before being accepted from suppliers? ☐ Yes ☒ No

Describe safeguards to prevent the use of materials that may generate off-spec product: ______

Is obsolete material returned to the supplier? ☒ Yes ☐ No
Is inventory used in first-in, first-out order? ☒ Yes ☐ No
Is the inventory system computerized? ☒ Yes ☐ No
Does the current inventory control system adequately prevent waste generation? ☒ Yes ☐ No

What information does the system track?
Total amount used; Amount Per Order

Is there a format personnel training program on material handling, spill prevention, proper storage techniques, and waste handling procedures? ☒ Yes ☐ No

Does the program include information on the safe handling of the types of drums, containers, and packages received? ☒ Yes ☐ No

Are written procedures available and easily accessible? ☒ Yes ☐ No

How often is training given and by whom? Bi-Annual by Safety Committee Chairman ( ) and Safety Committee member and load technician ( )

What spill containment methods are used? A chemical spill kit stands ready where chemicals are mixed and stored. This kit includes protective gear. (gloves, goggles, boots, respirator) Dikes, Sand, Floor Squeegies and mops.

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WORKSHEET
11

WASTE MINIMIZATION: Material Handling

B. DRUMS, CONTAINERS, AND PACKAGES

Are drums, packages, and containers inspected for damage before being accepted? [X] Yes [ ] No
Are employees trained in ways to safely handle the types of drums & packages received? [X] Yes [ ] No
Are they properly trained in handling of spilled raw materials? [X] Yes [ ] No
Are stored items protected from damage, contamination, or exposure to heat, light and air? [X] Yes [ ] No

Describe handling procedures for damaged items: Damaged containers are not accepted by our receiving personnel. These containers are sent back to the vendor via the delivery service.

Does the layout of the facility result in heavy traffic through the raw material storage area? [ ] Yes [X] No
(Heavy traffic increases the potential for contaminating raw materials with dirt or dust and for causing spilled materials to become dispersed throughout the facility.)
Can traffic through the storage area be reduced? [ ] Yes [X] No

To reduce the generation of empty containers and liquid wastes due to their cleaning, has the facility attempted to:

Purchase pre-mixed solutions to minimize measuring, mixing, and handling? [ ] Yes [X] No
Purchase solutions in recyclable containers? [ ] Yes [X] No
Other approaches (Describe ______) [ ] Yes [ ] No

Discuss the results of these attempts: ______

Are all empty bags, packages, and containers that contained hazardous materials segregated from those that contained non-hazardous wastes? Describe method currently used to dispose of hazardous waste:

All chemicals used are liquid. These containers are thoroughly rinsed with water that is added to the mix. The containers are then cut to prevent them being reused by others not aware of the contents.

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WORKSHEET
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WASTE MINIMIZATION:
Material Handling

C. BULK LIQUIDS HANDLING

What safeguards are in place to prevent spills and avoid ground contamination during the filling of storage tanks?

- High level shutdown/alarms ☐
- Flow totalizers with cutoff ☐
- Secondary containment ☐
- Other ☒

Describe the system:
Wet floor sensors with audible alarm for spills or leaks as soon as they occur.

Are air emissions from bulk chemical storage tanks controlled by means of:

- Conservation vents ☐
- Nitrogen blanketing ☐
- Absorber/Condenser ☐
- Other vapor loss control system ☒
- Absorber ☐

Describe the system:
Each 500 gallon tank has a tight fighting lid.

Are all storage tanks routinely monitored for leaks? If yes, describe procedure and monitoring frequency for aboveground/vaulted tanks:
Yes. Each day chemical levels are checked and tanks are suspended 12 inches to make leaks obvious.

Underground tanks:
NA

How are the liquids in these tanks dispensed to the users? (i.e., in small containers or hard piped.)
All chemicals are hardpiped directly to the processors.

Are pipes cleaned regularly? Also discuss the way pipes are cleaned and how the resulting waste is handled:
They retain a constant pressure created by gravity feed. Pipes are not drained and cleaned.

When a spill of liquid occurs in the facility, what cleanup methods are employed (e.g., wet or dry)? Also discuss the way in which the resulting wastes are handled: If a spill is small; sand, a mop, or wet vacum is used for pick-up. If spill is large; dikes are used to contain spill, wet vacum is used to pick-up. All liquids are then diluted 10:1 with water and discharged.

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WORKSHEET
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OPTION GENERATION: Material Handling

Meeting Format (e.g., brainstorming, nominal group technique) Small group discussions

Meeting Coordinator Plant Manager

Meeting Participants ________

Suggested Waste Minimization Options	Currently Done Y/N	Rationale/Remarks on Option
A. General Handling Techniques	Y	
Quality Control Check	Y	
Return obsolete Material to Supplier	Y	
Minimize Inventory	Y	
Computerize Inventory	Y	
Formal Training	Y	
Recycle Film Reels, Canisters, and Spools	Y	
B. Drums, Containers, and Packages	N	Will investigate options in future.
Raw Material Inspection	N	Is not feasible at this time.
Proper Storage/Handling	Y	
Pre-mixed Solutions	N	NA
Recyable Containers	N	Will contact vendor for information.
Bulk Delivery	Y	
Waste Segregation	Y	
C. Bulk Liquids Handling	Y	
High Level Shutdown/Alarm	Y	
Flow Totalizers with Cutoff	Y	
Secondary Containment	N	Not necessary in our set-up.
Air Emissions Control	Y	
Leak Monitoring	Y	
Spilled Material Reuse	N	Have never tried. Contamination?
Cleanup Methods to Promote Recycling	N	

Appendix B
Where to Get Help
Further Information on Pollution Prevention

Additional information on source reduction, reuse and recycling approaches to pollution prevention is available in EPA reports listed in this section, and through state programs and regional EPA offices (listed below) that offer technical and/or financial assistance in the areas of pollution prevention and treatment.

Waste exchanges have been established in some areas of the U.S. to put waste generators in contact with potential users of the waste. Twenty-four exchanges operating in the U.S. and Canada are listed.

U.S. EPA Reports on Waste Minimization

Waste Minimization Opportunity Assessment Manual. EPA/625/7-88/003.***

Waste Minimization Audit Report: Case Studies of Corrosive and Heavy Metal Waste Minimization Audit at a Specialty Steel Manufacturing Complex. Executive Summary. NTIS No. PB88 - 107180*

Waste Minimization Audit Report: Case Studies of Minimization of Solvent Waste for Parts Cleaning and from Electronic Capacitor Manufacturing Operation. Executive Summary. NTIS No. PB87 - 227013*

Waste Minimization Audit Report: Case Studies of Minimization of Cyanide Wastes from Electroplating Operations. Executive Summary. NTIS No. PB87 -229662.*

Report to Congress: Waste Minimization, Vols. I and II. EPA/530-SW-86-033 and -034 (Washington, D.C.:U.S.EPA,1986)**.

Waste Minimization - Issues and Options, Vols. I-III EPA/530-SW-86-041 through -043. (Washington, D.C.: U.S.EPA,1986**.

*Executive Summary available from EPA, WMDDRD, RREL, 26 W. Martin Luther King Dr., Cincinnati, OH 45268; full report available from the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA 22161.

**Available from the National Technical Information Service as a five-volume set, NTIS no. PB87 -114 328.

***Available from EPA ORD Publications, CERI, 26 W. Martin Luther King Drive, Cincinnati, OH 45268; (513-569-7562).

The Guides to Pollution Prevention manuals*** describe waste minimization options for specific industries. This is a continuing series which currently includes the following titles:.

Guides to Pollution Prevention: Paint Manufacturing Industry. EPA/625/7-90/005

Guides to Pollution Prevention: The Pesticide Formulating Industry. EPA/625/7-90/004

Guides to Pollution Prevention: The Commercial Printing Industry. EPA/625/7-90/008

Guides to Pollution Prevention: The Fabricated Metal Industry. EPA/625/7-90/006

Guides to Pollution Prevention For Selected Hospital Waste Streams. EPA/625/7-90/009

Guides to Pollution Prevention: Research and Educational Institutions. EPA/625/7-90/010

Guides to Pollution Prevention: The Printed Circuit Board Manufacturing Industry. EPA/625/7-90/007

Guides to Pollution Prevention: The Pharmaceutical Industry. EPA/625/7-91/017

Guides to Pollution Prevention: The Fiberglass Reinforced and Composite Plastic Industry. EPA/625/7-91/014

Guides to Pollution Prevention: The Automotive Repair Industry. EPA/625/7-91/013

Guides to Pollution Prevention: The Automotive Refinishing Industry. EPA/625/7-91/016

Guides to Pollution Prevention: The Marine Repair Industry. EPA/625/7-91/015

U.S. EPA Pollution Prevention Information Clearing House (PPIC): *Electronic Information Exchange System (EIES) - User Guide, Version 1.1*. EPA/600/9-89/086

Waste Reduction Technical /Financial/ Assistance Programs

The EPA Pollution Prevention Information Clearinghouse (PPIC) was established to help reduce industrial pollutants through technology transfer, education, and public awareness. PPIC collects and disseminates technical and other information on pollution prevention through a telephone hotline and an electronic information exchange network. Indexed bibliographies and abstracts of reports, publications, and case studies about pollution prevention are available. PPIC also lists a calendar of pertinent conferences and seminars; information about activities abroad and a directory of waste exchanges. Its Pollution Prevention Information Exchange System (PIES) can be accessed electronically 24 hours a day without fees.

For more information contact:

PIES Technical Assistance
Science Applications International Corp.
8400 Westpark Drive
McLean, VA 22102
(703) 821-4800

or

U.S. Environmental Protection Agency
401 M Street S. W.
Washington, D. C. 20460

Myles E. Morse
Office of Environmental Engineering
and Technology Demonstration
(202) 475-7161

Priscilla Flattery
Pollution Prevention Office
(202) 245-3557

The EPA's Office of Solid Waste and Emergency Response has a telephone call-in service to answer questions regarding RCRA and Superfund (CERCLA). The telephone numbers are:

(800) 424-9346 (outside the District of Columbia)

(202) 382-3000 (in the District of Columbia)

The following programs offer technical and/or financial assistance for waste minimization and treatment.

Alabama
Hazardous Material Management and
Resources Recovery Program
University of Alabama
P.O. Box 6373
Tuscaloosa, AL 35487-6373
(205) 348-8401

Alaska
Alaska Health Project
Waste Reduction Assistance Program
431 West Seventh Avenue, Suite 101
Anchorage, AK 99501
(907) 276-2864

Arkansas
Arkansas Industrial Development Commission
One State Capitol Mall
Little Rock, AR 72201
(501) 371-1370

California
Alternative Technology Division
Toxic Substances Control Program
California State Department of Health Services
714/744 P Street
Sacramento, CA 94234-7320
(916) 324-1807

Connecticut
Connecticut Hazardous Waste Management Service
Suite 360
900 Asylum Avenue
Hartford, CT 06105
(203) 244-2007

Florida
Waste Reduction Assistance Program
Florida Department of Environmental Regulation
2600 Blair Stone Road
Tallahassee, FL 32399-2400
(904) 488-0300

Georgia
Hazardous Waste Technical Assistance Program
Georgia Institute of Technology
Georgia Technical Research Institute
Environmental Health and Safety Division
O'Keefe Building, Room 027
Atlanta, GA 30332
(404) 894-3806

Environmental Protection Division
Georgia Department of Natural Resources
Floyd Towers East, Suite 1154
205 Butler Street
Atlanta, GA 30334
(404) 656-2833

Guam
Solid and Hazardous Waste Management Program
Guam Environmental Protection Agency
ITCE E. Harmon Plaza, Complex Unit D-107
130 Rojas Street
Harmon, Guam 96911
(671) 646-8863

Illinois
Hazardous Waste Research and Information Center
Illinois Department of Energy and Natural Resources
1 East Hazelwood Dr.
Champaign, IL 61820
(217) 333-8940

Illinois Waste Elimination Research Center
Pritzker Department of Environmental Engineering
Alumni Building, Room 102
Illinois Institute of Technology
3200 South Federal Street
Chicago, IL 60616
(313)567-3535

Indiana
Environmental Management and Education Program
Young Graduate House, Room 120
Purdue University
West Lafayette, IN 47907
(317) 494-5036

Indiana Department of Environmental Management
Office of Technical Assistance P.O. Box 6015
105 South Meridian Street
Indianapolis, IN 46206-6015
(317) 232-8172

Iowa
Center for Industrial Research and Service
205 Engineering Annex
Iowa State University
Ames, IA 50011
(515) 294-3420

Iowa Department of Natural Resources
Air Quality and Solid Waste Protection Bureau
Wallace State Office Building
900 East Grand Avenue
Des Moines, IA 50319-0034
(515) 281-8690

Kansas
Bureau of Waste Management
Department of Health and Environment
Forbesfield, Building 730
Topeka, KS 66620
(913) 269-1607

Kentucky
Division of Waste Management
Natural Resources and Environmental Protection Cabinet
18 Reilly Road
Frankfort, KY 40601
(502) 564-6716

Louisiana
Department of Environmental Quality
Office of Solid and Hazardous Waste
P.O. Box 44307
Baton Rouge, LA 70804
(504) 342-1354

Maryland
Maryland Hazardous Waste Facilities Siting Board
60 West Street, Suite 200 A
Annapolis, MD 21401
(301) 974-3432

Maryland Environmental Service
2020 Industrial Drive
Annapolis, MD 21401
(301) 269-3291
(800) 492-9188 (in Maryland)

Massachusetts
Office of Technical Assistance
Executive Office of Environmental Affairs
100 Cambridge Street, Room 1094
Boston, MA 02202
(617) 727-3260

Source Reduction Program
Massachusetts Department of Environmental Protection
1 Winter Street
Boston, MA 02108
(617) 292-5982

Michigan
Resource Recovery Section
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Minnesota
Minnesota Pollution Control Agency
Solid and Hazardous Waste Division
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St. Paul, MN 55155
(612) 296-6300

Minnesota Technical Assistance Program
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Minneapolis, MN 55414
(612) 627-4555
(800) 247-0015 (in Minnesota)

Missouri
State Environmental Improvement and Energy Resources Agency
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Jefferson City, MO 65102
(314) 751-4919

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New Hampshire Department of Environmental Sciences
Waste Management Division
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Concord, NH 03301-6509
(603) 271-2901

New Jersey
New Jersey Hazardous Waste Facilities
Siting Commission
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Trenton, NJ 08608
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(609) 292-1026

Hazardous Waste Advisement Program
Bureau of Regulation and Classification
New Jersey Department of Environmental Protection
401 East State Street
Trenton, NJ 08625
(609) 292-8341

Risk Reduction Unit
Office of Science and Research
New Jersey Department of Environmental Protection
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Trenton, NJ 08625
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New York
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Albany, NY 12205
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Department of Natural Resources and
Community Development
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Governor's Waste Management Board
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Raleigh, NC 27611
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Technical Assistance Unit
Solid and Hazardous Waste Management Branch
North Carolina Department of Human Resources
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Division of Solid and Hazardous Waste Management
Ohio Environmental Protection Agency
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Columbus, OH 43266-1049
(614) 481-7200

Ohio Technology Transfer Organization
Suite 200
65 East State Street
Columbus, OH 43266-0330
(614) 466-4286

Oklahoma
Industrial Waste Elimination Program
Oklahoma State Department of Health
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Oklahoma City, OK 73152
(405) 271-7353

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Oregon Hazardous Waste Reduction Program
Department of Environmental Quality
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Portland, OR 97204
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Pittsburgh, PA 15238
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Bureau of Waste Management
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Knoxville, TN 37996
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Virginia Department of Waste Management
11th Floor, Monroe Building
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Richmond, VA 23219
(804) 225-2667

Washington
Hazardous Waste Section
Mail Stop PV-11
Washington Department of Ecology
Olympia, WA 98504-8711
(206) 459-6322

Wisconsin
Bureau of Solid Waste Management
Wisconsin Department of Natural Resources
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Madison, WI 53707
(608) 267-3763

Wyoming
Solid Waste Management Program
Wyoming Department of Environmental Quality
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122 West 25th Street
Cheyenne, WY 82002

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