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EPA

Project Summary

Waste Minimization Opportunity Assessment: A Photofinishing Facility

EPA has developed a systematic approach to identify and implement options to reduce or eliminate hazardous waste. The approach is presented in a report entitled, "*Waste Minimization Opportunity Assessment Manual*" (EPA/625/7-88/003). To encourage use of this manual, EPA is conducting a series of assessment projects under the Waste Reduction Assessment Program (WRAP). This report describes the application of the waste minimization (WM) assessment procedure to a photofinishing facility in Cincinnati, OH. This facility volunteered to participate in the project and provided technical support during the study.

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

Introduction

The purpose of this project was to demonstrate the application of EPA's *Waste Minimization Opportunity Assessment Manual* to a retail photofinishing facility. This manual provides a systematic planned procedure for identifying ways to reduce or eliminate waste.

This project was conducted in cooperation with Accuphoto, a retail photofinishing facility located in Cincinnati, OH. Accuphoto volunteered for the project and provided support throughout the effort. This facility was selected for the project based on their willingness to cooperate, the potential at the facility for WM, and the fact that Accuphoto is typical of facilities within this industry segment.

The results of this project will be particularly applicable to small and medium-sized photofinishing facilities. The equipment and processes used by Accuphoto are commonly employed by "minilabs," which represent a large portion of the photofinishing retail industry. These WM technologies and methodologies are generally low-capital options that do not require extensive technical support to implement. Larger photofinishing companies may find other techniques to be more efficient and cost effective and are more likely to use automated equipment and techniques that require monitoring by technical staff. Further, larger firms can take advantage of economies-of-scale to increase the profitability of waste minimization options.

Procedure

The WM assessment procedure is a systematic framework that can be used by a facility's own employees to identify WM opportunities. As a structured program, it provides intermediate milestones and a step-by-step procedure to (1) understand the facility's processes and wastes, (2) identify options for reducing waste, and (3) determine if the options are technically and economically feasible to justify implementation. These procedures consist of four major steps: (1) planning and organization, (2) assessment, (3) feasibility analysis, and (4) implementation. This project completed the first three steps of the procedures for the various photofinishing processes used at Accuphoto. Implementation of the recommended options is at the discretion of the host facility. The focus for this project was on the film and print processing operations—processes for color and black and white (B&W) films and papers.

Accuphoto staff participated in the survey by providing background information and data about the facility, and its equipment, processes, operating procedures, waste generation, and WM options. They also provided ideas for WM and input to the ranking criteria used for evaluating WM options. This information was used later in the study to incorporate Accuphoto's preferences in the evaluation process.

The key analytical datum with respect to photographic waste is the silver concentration of spent process chemicals and wash waters. Because silver is important in terms of its economic value and also, as a commonly regulated pollutant, the silver concentration of each wastestream is important in evaluating WM options and environmental impacts. Since wastestream data were unavailable for this specific facility, they were estimated using data from the literature.

The Accuphoto Facility provides photographic processes for color film (C-41), color paper (RA-4 and EP-2), black and white film (T-max), and black and white paper. All spent process chemicals and wash waters are discharged into the sanitary sewer. The B&W film and paper processes and the EP-2 process are plumbed directly to the sewer drain. The RA-4 and C-41 processes discharge to internal storage vessels that are periodically drained into carboys. The carboys are emptied into a sink that discharges to a sewer drain.

All solid wastes are collected by a city solid waste contractor. Chemical containers are rinsed before being discarded with other refuse. The costs of water and sewer and solid waste disposal are included in the cost of the Accuphoto's facility lease.

Results and Discussion

Eight options were considered to be potentially applicable to Accuphoto.

Option 1. Wash Water Control

Wash water is currently used for the EP-2 color film development process and the B&W paper process. The wash water is turned on each production day at approximately 7 a.m. and shut off at 7 p.m; water use is therefore continuous during the day. Production, however, is not continuous. Because each developing process is typically used only 2 hr per day, water is wasted for approximately 8 hr per day. However, because of the semi-automated nature of these production processes, operators are not typically aware of exactly when the process is complete. Further, operator control is generally not sufficient to provide consistent water savings.

Option 1 includes the equipment needed to automatically shut off water during non-production periods. A simple way to achieve this goal is installing a timer control system, a switch, timer, and solenoid valve. In use, the operator would push a button on the switch, and the timer would be activated; this would, in turn, activate the solenoid and allow water to flow. After a preset time period (user adjustable), the timer and solenoid would deactivate, shutting off the water. The timer would be preset to the normal or maximum production time depending on the nature of the operation.

Further water reduction for these two processes may be possible by evaluating the water flow rate. The present flow of 2 gpm may be excessive, especially for the EP-2 process, which has an efficient counter current rinse arrangement. A silver test paper could determine an acceptable flow rate.

Option 2. Silver Recovery - Metal Replacement Cartridges

Silver is present in the various spent photographic chemicals and wastewaters. The solutions themselves are not formulated with silver; rather, silver is present in the emulsion on films and papers as light-sensitive silver halide. During processing, the developer changes the exposed silver halide to metallic silver. For B&W films and papers, only the unexposed silver halide (typically 80%) is removed from the emulsion during the fixer stage. The balance of the silver remains on the paper or film. For color films and papers, a dye is formed at the sites of the developed silver. Then all silver is removed during a bleach fix stage or in subsequent washes and process solutions.

The metal replacement cartridge (MRC) is a device widely used in the photographic industry for silver recovery, both as a stand-alone method and in conjunction with other recovery technologies. Metal replacement cartridges are particularly popular with small and mid-size laboratories because of the associated low capital costs and the relatively high silver recovery efficiency.

Option 3. Silver Recovery - Electrowinning

Option 3 is an equipment-related option involving the use of an electrowinning device. With this technology, which closely resembles electroplating, a direct electric current is passed through a concentrated silver solution from anodes to cathodes. This causes the silver to plate out onto the cathode in a nearly pure metallic form.

The selection from the wide range of commercially available equipment depends on the solution volume or flow rate, the concentration of silver, and the level of automation and design sophistication that the user desires.

Option 4. Electrowinning with MRC Tailing

With this option, based on the use of an electrolytic unit described in Option 3, metal replacement cartridges are used to polish the effluent from electrowinning.

The recovery capability of Option 4 is equivalent to Option 3 plus the removal of silver from the effluent of electrowinning. The average effluent will be desilvered from 500 mg/L to approximately 10 mg/L. By using the same type of MRC described in Option 2, only one 5-gal cartridge will be consumed each year. Because of oxidation of the steel wool, however, the units may become fouled before they reach capacity, and more frequent changes may be required.

Option 5. Recovery of Silver - Ion Exchange

Ion exchange is a silver recovery technique applicable to large volumes of low concentration solution such as wash waters. Photofinishing shops using this technique either (1) have sufficiently large volumes of dilute wastewaters such that silver recovery from these streams is economical, and/or (2) must reduce an effluent to a low silver concentration to meet a discharge limitation.

Typically, an ion exchange unit consists of a canister or column that holds the ion exchange resin; regeneration equipment; and auxiliary items such as pumps, valves, filters, controls, and instrumentation. During operation, the wastewater is pumped through the column and the silver is removed onto the ion exchange resin. When the capacity of the resin is reached, the silver is stripped from the resin in a concentrated form using a regeneration solution.

Option 6. Recovery of Fixer

To recycle the fixer, electrolytic recovery can desilver the spent fixer. This method does not add contaminants to the fixer; however, electrolysis will produce some changes in the fixer. Two changes that have been identified are 1) sulfite is consumed and 2) the fixer pH is lowered. Sulfite consumption will eventually breakdown the thiosulfate complex to form sulfide. Sulfide affects the ability of the fixer to remove silver and also hinders the plating capability of the electrolytic unit. Significant changes in pH may also affect the fixer quality and the silver recovery process.

To recover fixer, a dedicated electrolytic unit is needed — one used only for recycling fixer because the recovery process must be done on a continuous basis rather than as a batch operation. Batch treatment of fixer would result in an inconsistent chemical composition, and control of the photographic process would be hampered. Further, during batch recovery of silver, it would be necessary to constantly monitor the silver concentration and current density. If too much current is used or the recovery unit is left on too long, the thiosulfate in the fixer will break down to form sulfide ion and silver sulfide.

A continuous recovery system can reduce fixer replenishment up to 75% by maintaining approximately a 500 mg/L silver concentration in the fixer. In this mode, silver recovery can be enhanced by using a metal replacement cartridge to recover silver from the blow-down of the electrolytic recovery process.

Option 7. Recovery of Bleach Fix

Bleach fix can be recycled using a continuous electrolytic system as described for fixer recovery. The chemical composition of bleach fix makes electrolytic silver recovery difficult to control, however, and the process is generally inefficient.

The method most commonly recommended for bleach fix recovery is the three-step desilvering process with metal replacement cartridges: 1) silver recovery, 2) a ferrous-EDTA complex oxidized back to ferric-EDTA to restore bleaching ability, and 3) chemicals lost through carry-over with the film or paper added to bring the solution up to replenisher strength.

The silver recovery step should be performed using two metal recovery cartridges in series. The second unit will protect against excessive silver carryover when the first unit approaches exhaustion. During silver recovery, ferric-EDTA is converted to ferrous-EDTA. Because the primary bleach reaction involves ferric-EDTA, the solution can be aerated to oxidize ferrous-EDTA back to ferric-EDTA. Following aeration, the solution can be returned to the holding tank for reuse.

Option 8. Recovery of Developer

Ion exchange can be used to recover color developer. This technology removes bromide ions and decomposition products that cause the developer to become spent. Recovery has been successful with the use of a strong-base anion-exchange resin. The ion exchange resin has been traditionally regenerated with the use of sulfuric acid, and, in a few cases, with sodium hydroxide. Experimentally, a new regenerant system composed of 1.0 M sodium chloride followed by 0.5 M sodium bicarbonate has been successfully used. The advantage of this system is the non-corrosive nature of the regeneration wastestreams. Because of the high capital investment required for ion exchange equipment, the recovery of developer is only applicable to large photofinishing facilities.

Conclusions and Recommendations

The technical feasibility evaluation initially determines the nature of the WM options, either equipment-related, personnel/procedure-related, or materials-related. For each of the three types of WM options, specific information and data are required. For equipment-related options, the information requirements relate to the state of the technology, availability of equipment, performance specifications, testing, space and utilities, production effects, and training. For personnel/procedure-related options, the required information relates to training and operating instruction changes. For materials-related options, the required information relates to production impacts, storage and handling, training, and testing. The WM options evaluated during this project were all equipment-related options.

Based on the results of the assessment phase, five WM options were selected for further evaluation in the feasibility analysis phase. The technical and economic results of the feasibility analysis phase are summarized in Table 1. This table indicates the total capital investment, the net operating cost savings, and the payback period (total capital investment/net operating cost savings) for each option.

The results of the study indicate that the fastest payback would be realized from Options 1 and 7. Option 1 involves conserving water by installing wash water controls; Option 7 involves recycling bleach fix and recovering silver with the use of MRCs. Bleach fix recovery will require some technical evaluation by Accuphoto. If Accuphoto decides not to recycle bleach fix (Option 7), then the fastest payback for silver recovery is Option 2 (use of MRCs). If production increases significantly in the future, the payback period for electrowinning (Options 3 and 4) becomes increasingly attractive. For example, if a 2.3 multiple increase in production (this factor relates to the capacity of the selected electrowinning unit) is assumed, the payback periods for Options 3 and 4 is 1.1 yr and 0.9 yr, respectively. The payback period for Option 7 (bleach fix and silver recovery) reduces to 0.3 yr. Using the same production increase, the Option 2 payback period reduces at a slower rate to 0.4 years. A more in-depth cash flow analysis over the life of a project considering equipment depreciation, tax rates, loan rates, and other factors not evaluated during this study could be performed by Accuphoto.

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Table 1. Summary of Waste Minimization Feasibility Analysis Phase

Waste Minimization Option	Applicable Wastestreams§	Total Capital Investment, $	Net Operating Cost Savings, $/Yr	Payback Period, Yr
1. Wash water control	EP-2 bleach fix wash; B&W paper process fixer wash	$ 675	$1,436	0.47
2. Silver recovery using metal replacement cartridges*	C-41 bleach, fixer and stabilizer; RA-4 bleach fix and stabilizer; EP-2 bleach fix and bleach fix wash; T-Max fixer wash; B&W paper process fixer wash	$1,071	$1,325	0.81
3. Silver recovery using electrowinning†	C-41 bleach and fixer; RA-4 bleach fix ; EP-2 bleach fix; T-Max fixer; B&W paper process fixer	$3,510	$1,414	2.48
4. Silver recovery using electrowinning with MRC tailing†	C-41 bleach and fixer; RA-4 bleach fix; EP-2 fix; T-Max fixer; B&W paper process fixer	$3,667	$1,757	2.08
7. Recycle of bleach fix and silver using MRCs‡	RA-4 bleach fix; EP-2 bleach fix	$1,571	$2,508	0.63

*Streams with 5 troy oz or greater per year.
†Streams with a silver concentration >500 mg/L.
‡Spent bleach fix solutions.
§Wastes association with color film process C-41, color paper processes RA-4 and EP-2, B&W film process T-Max, and B&W paper process.

This summary was prepared by staff of Science Applications International Corp., McLean, VA 22102.
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The complete report, entitled "Waste Minimization Opportunity Assessment: A Photofinishing Facility " (Order No. PB-91 231 530/AS; Cost: $26.00, subject to change) will be available only from:
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