PHOTOPROCESSING SYSTEMS AND PRINTING INKS

COMMONLY OBSERVED PRACTICES

PHOTOPROCESSING SYSTEMS

Materials used in graphic arts photography include film that has a paper, plastic or glass base covered with a light-sensitive coating called a photographic emulsion. This emulsion is usually composed of silver halide salts in gelatin. Most photographic films are made of polyester.

Commonly used developing agents contain an accelerator, a preservative and a restrainer. Frequently used chemicals are hydroquinone and metol. Developing action is stopped by immersing film into a fix bath of sodium thiosulfate (hypo), ammonium thiosulfate, or sodium hyposulfite. Hypo is the major ingredient of fixing baths, with potassium alum, acetic acid, and sodium sulfite also present. Alkaline developer is carried over into the fix bath on films and prints immersed in the fixer. An acid stop bath is often used prior to the fixing bath to stop the action of the developing solutions and to prevent contamination of the fix bath.

After the negative or positive is fixed, some of the fix bath chemicals (hypo) remain in the gelatin emulsion layer. If these chemicals are not removed they can react with the silver to form yellow-brown silver sulfide. To prevent sulfide formation, fix chemicals are washed from the emulsion in a water bath until the hypo is dissolved out. Small amounts of processing chemicals and silver rinsed from film can accumulate in the final water bath.

Nonhazardous wastes generated during image processing steps include empty containers, used film packages, film spools, and outdated materials. The primary hazardous waste stream is silver containing materials such as used film, and silver-bearing chemistries, including rinsing water. Prior to discharge of silver-bearing water solutions, local, state and federal wastewater and hazardous waste requirements must be met.

INKS

Both traditional water-based printing processes and waterless printing technologies are used by printers. Ink, fountain solution, water quality, substrate and press adjustment all play a role in achieving the proper image.

Traditionally, lithographic inks have been petroleum-based. Pigments used in these inks are primarily inorganic metals. Ink additives include solvents, varnishes and dryers. Recently, manufacturers have developed many new ink formulations using vegetable and soy-based oil and fewer heavy metal pigments.

Wastes generated include outdated inks, dried ink and ink skins, excess ink from cleaning the ink tray, empty ink containers and volatile organic compound emissions (VOC's) from petroleum-based inks.

GENERAL POLLUTION PREVENTION OPTIONS

- Storage and Handling
- Inventory and Purchasing
- Improved Processes
- Material Substitution
- Electronic Technology

The amount of photoprocessing and ink wastes can be dramatically reduced through simple techniques and the use of specialized equipment. Following is a summary of pollution prevention options.

Storage and Handling - Photoprocessing Material and Ink

- Store photoprocessing chemicals and ink following manufacturers direction
- Storage area should be free of dust and other contaminants
- Inspect material upon receiving a shipment
- Inspect material prior to use

Photoprocessing chemicals and inks sensitive to temperature and light should be stored according to manufacturers directions. Improper raw material storage and handling can result in spoilage and out-dated or expired material. Many photoprocessing and plate developing chemicals are light and temperature sensitive. Chemical containers list recommended storage conditions and shelf life. These recommendations should be followed explicitly. Storage areas should be free of dust or other contaminants that could destroy raw materials.

All materials should be inspected upon arrival; unacceptable or damaged product should be returned to the manufacturer or supplier. Materials should also be inspected prior to use, this eliminates printing an unacceptable product.

Inventory and Purchasing - Photoprocessing Material and Ink

- Implement first-in, first-out material usage to prevent expired shelf life
- Purchase computerized inventory systems
- Purchase special order material in quantities that can be used prior to expiration dates
- Test expired material for effectiveness prior to disposal or recycling
- High volume material should be purchased in bulk
- Recycle product containers or return them in exchange for full containers

Inventory managed using the first-in, first-out practices (product with oldest purchase date and/or closest expiration date is used first) will help reduce expired shelf life. Computerized inventory systems, while effective in reducing wastes, are expensive ($7,500 to $300,000) and may be cost effective for only the largest printers. Systems that only track inventory are less expensive. Specialty or rarely used materials should be purchased in quantities that will allow complete use prior to product expiration whenever possible. Product that is expired should not be disposed until it is tested for effectiveness, expiration dates are estimates and many factors affect their accuracy.

High volume materials can be purchased in bulk, usually at a reduced cost per unit. Arrangements should be made with the vendor to recycle the containers or to return them in exchange for full containers of new product.

Improved Processes - Photoprocessing

- Use an acid stop bath prior to fixing
- Use hand squeegees
- Purchase automated processing equipment
- Closely monitor chemical replenishment
- Purchase automatic replenishing systems
- Reduce wastewater quantities and water usage
- Employ countercurrent rinsing techniques

- Use automatic flow and heat controls
- Use rinse bath agitators
- Recycle rinse water
- Keep containers closed: use floating lids, add glass marbles to prevent evaporation and oxidation of chemicals
- Reuse fixer
- Recycle silver either on site or off site
- Recycle scrap film and paper
- Join printing industry trade and professional associations
- Attend Graphics Arts and Printers Conferences, Seminars and Tradeshows

Immersion of developed film into an acid stop bath prior to fixing will help eliminate chemical carryover to the fixer. Using hand squeegees to wipe excess liquid in a non-automated processing system can reduce chemical contamination in carryover from one process bath to the next bath by 50 percent. Caution must be exercised when using hand squeegees, film may be damaged if the image has not hardened completely. Automated processing equipment that has waste minimization features, such as squeegees, should be considered when purchasing new equipment. Minimizing fix bath contamination increases recyclability, extends the life of chemicals baths, and reduces the quantity of replenisher chemistry required to bring the fix solution back to operating strength.

Closely monitor chemical replenishment. Automatic replenishing systems can improve the accuracy of renewing fix solutions and effectively monitor and reduce quantities of chemistry used.

Cost of automated equipment for photoprocessing systems varies greatly, depending on factors such as type and size of processor, type and quantity of film processed, and degree of automation. Several vendors and manufacturers should be consulted to determine the most effective automated processing equipment for each business.

Counter-current rinsing reduces the amount of contamination in processing solutions as well as conserves water when compared to traditional parallel tank wash systems. Water from prior rinsing is used in the initial film wash; fresh water is introduced only at the final rinse stage, where most of the contamination has been previously removed by earlier stage rinsing.

Automatic rinse water flow and controls can be installed in place of continuous flow systems that start consuming water at the beginning of the work day and run continuously, whether film is being processed or not. It has been suggested that automatic water flow controls should be set to insure complete water changeout in the tray once every 5 minutes. The method by which the water enters and leaves the washing tank also affects the efficiency of the washing process. Best results are obtained when the water enters at the bottom of the tray and leaves through the top of the tray. A moderately warm wash water (80°F.) helps remove the hypo. Automatic and temperature flow controls when used in conjunction with mechanical agitation, can decrease time required for removal of hypo by 30 percent.

Recycle rinse water using one of the many systems on the market. Although the cost of consuming water is not typically an issue of concern, water conservation measures should be followed whenever possible. Water recycling equipment capital cost can be as much as $4,000 + depending on the size and complexity of the system. A 90-95 percent reduction in water usage is common with these systems. In addition to reduced water consumption, the time spent cleaning the processor is reduced, and processor productivity and product quality may be improved. Recycling equipment maintenance includes regular addition of chemical biocides and replacement and disposal of spent filters. Spent filters may contain a high concentration of silver and may be a considered hazardous, therefore a hazardous /nonhazardous waste determination (i.e., TCLP test) is advised prior to disposal.

Keep chemical containers closed. Floating lids can be used to reduce the contamination and evaporative losses in bleach and developer tanks. If appropriate, use glass marbles to raise the liquid level of process chemicals to the lid level. Keeping containers closed and liquid to the top will extend chemical life by reducing the amount of oxygen the liquid is exposed to. Cost of floating lids, marbles and employee training is minimal compared to savings from reduced material loss.

Fixer should be reused when possible. Optimize usage of all chemistries by consulting the product manufacturers to determine which can be reused and the steps required to ensure a quality finished product. Purchase and use fixers that can be recycled.

Developer can be recycled and replenishment chemistry can be reduced by 60 to 75 percent. The current cost of developer recycling technology can range from $4,000 to $9,500.

Silver can be removed and recycled from fixer and bleach-fix. As much as 80 percent of the total silver processed for black and white and almost 100 percent of the silver in process color work will end up in the fixer or bleach-fix solution. Silver is also present in rinse water following the fix step due to carry over. To remove silver to levels below regulatory limits (5ppm or local level) a combination approach using a primary silver recovery unit to remove the bulk of silver in combination with a “tailing” unit to remove residual silver should be used.

The benefit of silver recovery is dependent on the current market prices for silver. Recovered silver flake can be sold as high as 80 percent of the silver market value and desilvered fixer can potentially be reused.

Silver recovery can be conducted using two basic approaches: on-site recovery using commercially available equipment or off-site recovery through a silver recycling service. Recycling companies will provide pick up and recycling services to a print shop. Some recycling services retain a percentage of the recovered silver’s value as payment, while others may charge for their services. Recently, photoprocessing chemistry manufacturers have begun recycling programs for printers using their chemistries. Prior to signing on to a new program, a business should accurately determine the current quantities of chemistry being used, stored and disposed of each calendar month and compare this with the projected recycling program quantities. If the quantities of hazardous waste (i.e. spent fixer or caustic developer) stored on site or generated per month exceed their current generator category quantity limits, the business could be in violation of hazardous waste regulations and may be subject to fines and/or the requirements of a more stringently regulated generator category. In addition, silver containing wastes cannot be stored on site for purposes of ‘speculative accumulation’.

Three common types of in-house silver recovery methods are used by photoprocessors. The first two, electrolytic (electrowinning) and metallic replacement are used to recover silver from fix solution. The third method, ion exchange is used to remove silver from rinse water. Ozone oxidation, reverse osmosis and chemical precipitation are other less frequently used methods to recover silver.

1. Electrolytic units can be used as a batch recovery system, a continuous recovery system or as a recirculating recovery system.

   In electrolytic batch recovery, overflow fixer is collected in a tank and stored. When sufficient volumes have accumulated, the waste fixer is pumped to an electrolytic cell for silver removal.

Batch system cells are usually designed to desilver spent fix at initial silver concentrations of about 5,000 mg/l. After batch recovery the effluent typically contains 200-500 mg/l of silver.

Continuous electrolytic recovery units must be carefully sized to allow sufficient fixer residence time for optimal plating out of silver. Some units can sense silver concentrations and will automatically adjust current densities.

Recirculating electrolytic silver recovery systems are installed "in-line" and remove silver at approximately the same rate it is added by film processing. A continuous stream of fixer from in-use process tanks is recirculated through the unit, silver is removed and the fix is returned to the process tank for reuse. Processors must be equipped with a circulation pump and a separate electrolytic unit. Fix chemistry that has had silver electrolytically removed can be replenished and reused.

Factors which affect the operation and efficiency of electrolytic silver recovery systems are as follows:

- ✓ **Silver Concentration -** Electrolytic recovery efficiency is directly related to the silver concentration of the fixer. The higher the silver concentration, the higher the plating efficiency; the lower the concentration, the lower the efficiency. When silver concentration is below 1 gram/liter (0.12 troy oz./gal), plating efficiency and plating current fall off rapidly, reducing the recovery rate of the unit.
- ✓ **Type of Fixer -** The type of fixer can greatly affect the electrolytic recovery process and the type of electrolytic cell required. For example, bleach-fix solutions require a specially designed electrolytic system. A sufficient amount of sodium sulfite must be present in the fixer for the electrolytic process to work properly. Special "electro" fixer is available with increased concentrations of sulfite.
- ✓ **Line Voltage -** Another factor that can reduce plating efficiency is line voltage. Too low a voltage will cause reduced plating. If the voltage is too high the equipment will not operate properly.
- ✓ **pH -** The pH of the fixer can influence the plating efficiency of the recovery cell. Too high and silver may indiscriminately plate on all surfaces, including inside the processor itself.
- ✓ **Specially coated paper kits -** These kits are available to estimate the silver concentration, sulfite concentration and pH of the fixer. These inexpensive aids will help maximize silver recovery efficiency.

Typically, fixer solution that has been desilvered by electrolytic recovery methods will still contain higher than allowable levels of silver for discharge to the sanitary sewer. Acceptable levels of silver in wastewater vary widely; the local wastewater treatment plant superintendent can provide information concerning the levels of silver allowable for discharge in your area. Use of a follow-up recovery method or tailing method such as a metallic exchange canister is advised and should remove silver to allowable levels.

Cost of electrolytic units varies from approximately $400 to $5,000, based on site-specific factors. Electrolytic units plate a nearly pure silver flake on the cathode making the recovered silver flake value close to commodity market prices. The desilvered fixer can be replenished and reused.

2. The metallic replacement method for silver recovery is based on the principle that a more active metal (iron, zinc or aluminum) will replace a less active metal (silver) in solution. Spent fixing bath is passed through a canister or bucket containing steel wool or a mesh screen. The silver settles to the bottom of the canister as a sludge. The silver-bearing sludge needs to be refined further, therefore, its resale value is considerably lower than electrolytic recovered silver.

   A simple method for determining the amount of silver that a recovery system should yield is based on multiplying the silver concentration of the solutions entering the recovery cartridge by the volume of solution being treated. Specially designed silver estimating test papers, impregnated with a chemical substance that changes colors according to the amount of silver present in a solution, are used to determine the silver concentration. These test papers should also be used to determine the effluent concentration from the final cartridge. To test for silver levels of less than 1 gram/liter, soak the test papers for 1 hour before comparing to the color indicator.

   If a canister fails to collect silver or the silver yield does not meet expectations, any of the following may be the cause: type of film being processed, exposure level, processing work load, replenishment rate, solution carry-out, obstruction of solution flow, channeling, flow rate, incorrect type of recovery cartridge, incorrect installation, chemical condition of the fixing solution or pH of the fixer. Cartridge manufacturers and vendors are the best resource to diagnosis and solve problems associated with their equipment.

   A series of canisters is recommended for optimal silver recovery. When canisters are used in series, the first canister removes the bulk of the silver, and the second polishes the effluent of the first and also serves as a safety factor if the first unit is overloaded. When the first canister is exhausted, the second becomes the first, and a fresh unit replaces the second. Change out has been recommended when the silver in the effluent of the first cartridge reaches 25 percent of the influent concentration. For most effective operation, the pH of the solutions passing through the metallic replacement canister should be between 5 and 5.5. Below pH 4, the steel wool dis solves too rapidly, above 6.5, the replacement reaction is so slow that silver removal is incomplete. Proper pH control is critical to high silver recovery in metallic replacement canisters.

   A metallic replacement canister can capture approximately 85 percent of the recoverable silver in the form of sludge. Fixer that is desilvered using a metallic replacement bucket can not be reused as fix chemistry because of the excessive iron concentration (~4,000 mg/l) in the effluent. Metallic replacement buckets, used in series, may remove silver to levels acceptable for discharge to the sanitary sewer.

   Cost of metallic replacement canisters range from approximately $50 to $500. Additional expense includes further refining of the silver, disposal cost of desilvered fix chemistry and purchase cost of replacement chemistry.

3. Ion exchange is the reversible exchange of ions between a solid resin and a liquid. The silver-thiosulfate complex has a high affinity for the resin making it difficult to reclaim the silver and regenerate the resin. A common problem is system plugging by suspended matter, such as gelatin. Ion exchange silver recovery is used to polish silver-bearing rinse water. It can produce effluent with silver concentrations as low as 0.1 ppm and recover as much as 98 percent of the silver. Cost of ion exchange systems range from $3,300 to $4,400 and are typically not cost effective for any but the largest printers, unless they are necessary to reduce silver concentration to acceptable levels for sewer discharge.

Scrap film and paper contain silver salts or elemental silver. Silver recovery services may agree to recycle scrap film and paper along with the silver recovered from spent fixer.

Printing industry trade and professional associations are an excellent source for product and process information. Graphics arts and printing conferences throughout the country provide "one-stop" shopping for information on costs and benefits of automation in photoprocessing. New technologies are introduced and demonstrated through trade associations and conferences. Professional association membership dues, benefits, and related cost of attendance at conferences and meetings will vary widely. Cost of membership dues may be tax deductible.

Improved Processes - Ink

- Dedicate presses for specific colors and for "hazardous ink" only
- Use a standard ink sequence for process colors
- Schedule print runs from lighter to darker colors
- Improve accuracy in job estimation
- Counsel customers about environmental impact of hazardous materials
- Use an antiskinning spray
- Train employees to use retrofitted or new equipment properly
- Purchase and use a computer controlled mixing program
- Use a digital scale for accurate measurements

Dedicate presses for specific colors and for "hazardous ink" only to decrease the number of cleanings needed for each press and the quantity of ink wasted. Use a standard ink sequence for process colors. Schedule runs from lighter to darker colors to decrease the amount of cleaning necessary. Improve accuracy in job estimation and "prethink" printing jobs. Counsel customers about the environmental impact associated with particular color, paper or printing method choices. Make sure that print jobs reflect the true cost of doing business and disposing of hazardous waste.

Use a computer controlled mixing program and digital scale for mixing colors. Computer mixing software allows the printer to custom mix any ink color from colors already in inventory, thereby decreasing the purchase of new colors and increasing the use of instock colors. Use a digital scale to accurately measure ink formulations and remove the guesswork of mixing colors. In one case study, a printer's estimated cost to purchase the hardware, software and digital scale for the mixing program was approximately $2,500. The company reduced in-house ink inventory 40 to 50 percent. Problems associated with ink skinning were attributed to operator inexperience using the mixing program and the high number of jobs requiring a quick drying ink. Existing inventory had been purchased with dryers premixed into the ink. In the future, ink dryers will be purchased separately and added only when needed.

Material Substitution - Photoprocessing

- Ask vendors for nonhazardous chemical substitutes that do not contain mercury or cyanide salts for intensifiers and reducers
- Ask vendors for nonhazardous developers and finishers
- Accept only nonhazardous samples of product
- Request and read Material Safety Data Sheets
- Use silverless films such as diazo, vesicular, photopolymer, electrostatic, or selenium-based
- Use pre-sensitized lithographic plates, and discontinue use of etched plates.
- Use water-developed plates.

Vendors are excellent sources of information about substitutes for hazardous chemicals, films and plates. Request that vendors regularly provide literature about new or less toxic materials to staff. Use caution when accepting samples; be sure that the product does not contain other hazardous components that will require costly disposal. Many commonly used photographic intensifiers and reducers contain hazardous compounds, such as mercury or cyanide salts. Nonhazardous developers and finishers are available that are reported to be nontoxic with flash points over 200° F. Read labels and Material Safety Data Sheets (MSDS) before purchasing products.

Presensitized lithographic plates are an excellent alternative to metal etched plates. Some presensitized plates are processed with water only, further eliminating potentially hazardous wastes. Plates can also be produced directly from copy or artwork. Electronic systems are making a strong appearance on the market that totally eliminate the photoprocessing step.

Material Substitution - Ink

- Vegetable/soy inks
- Ultraviolet curable inks (UVC)
- Electron beam curable inks (EBC)
- Water washable ink systems
- Waterless inks

Cost of material substitutions will vary and should be selected accordingly. Benefits include reduced quantity of hazardous waste generated, reduced volatile organic compounds (VOC's), decreased disposal costs and possibly reduced handling, storage and disposal requirements.

Vegetable- or soy-based inks have many benefits. Environmentally, these inks reduce VOC emissions, are easier to recycle and may be nonhazardous. They are also made from a renewable resource. Drying times for vegetable/soy inks has been a problem but has been overcome with the addition of dryers and drying powders. Currently, soy inks are 10 - 15 percent more expensive than petroleum-based inks, but may show a 25 percent increase in print capability. Soy inks generate less waste because maintaining the correct water balance is much easier. The ink is clear which means pigments show through better producing brighter colors and less dot gain. Soy inks are rub resistant and lower quality paper can be used. As formulations improve, many printers have achieved increased coverage and excellent color with most soy ink except black, which remains problematic. Overall, vegetable/soy inks are the most economically feasible substitute for petroleum-based inks.

Ultraviolet and electron beam curable inks will not cure until exposed to either electron beam or ultraviolet energy and, therefore, can be left in the fountain overnight without skinning. This decreases both press cleaning time and waste ink generation. Also UVC and EBC inks do not emit VOC's because they contain no solvents. EBC and UVC inks are not easily recycled and both inks cost up to two times more than traditional inks. The major drawback is the high equipment costs and worker exposure to X-ray radiation. A good EBC system can cost $1 million, while UVC systems cost about $200,000 for equipment and installation. Waterless inks are not necessarily less toxic or hazardous than other ink types, but the waterless printing system as a whole generates considerably less VOC emissions than traditional lithographic processes. Major drawback of this technology is high equipment costs and employee training. Waterless technologies produce a very high quality product but many customers are not willing to pay the extra expense.

Electronic Technology - Photoprocessing

Prepress has undergone tremendous technological change from the expansion of electronic capabilities and the explosion of computer chip technology. The goal of electronic prepress is to create a completely digital master copy. This may be accomplished using high-end computer systems that electronically combine type, drawings, and images. Electronic prepress and imaging may involve preparing text using a personal computer to create disk files, to create page layout, typesetting, and to paint and draw graphics. Editing is immediate and easily manipulated by composition software programs.

Lasers can be used to scan images and make plates. Most recently, images can be created electronically by using a digital camera. The camera captures an image, digitizes it and either stores the image for input at a later time or immediately transports the digitized image to a computer for editing or enhancement. The entire procedure results in no film or processing wastes.

The obvious advantages of electronic prepress is speed, reduced prepress costs associated with traditional methods, labor savings, editing time and ease, the ability to integrate a number of files on disk, and unlimited creative options. A major environmental impact of electronic prepress is the opportunity to reduce or prevent pollution (silver-bearing wastes) generated using traditional methods.

Disadvantages include high initial cost of acquiring the necessary computer hardware and software, scanners, and expansion or add-on technologies such as digital cameras. Training will be required for technicians.

Many businesses find that a combination of traditional and desktop publishing works well and is cost-effective.

COST/BENEFITANALYSIS

The following formulas and comparison tables have been created to help printers begin the process of calculating the cost and benefit provided by implementing pollution prevention practices. Each business must enter it's own data into the formulas to obtain accurate cost/benefit information for their situation. Example values for costs and quantities of material used or wasted are estimates and may not accurately reflect true costs and benefits. Comparison tables should be used to weigh the basic difference between options. In-depth research into each option should be conducted before making product, process or equipment changes.

Storage and Handling - Photoprocessing Material and Ink

The cost of improved storage and handling practices includes employee time and costs associated with proper waste disposal of outdated or expired materials. Disposal costs may be a one time only expense if proper storage and handling practices are consistently followed. The benefit (savings) is relative to the quantities of materials that historically have been wasted, the replacement cost of those materials and disposal costs for wasted material. One intangible benefit is the decreased business liability for mismanagement, (improper storage and/or waste characterization) of potentially hazardous wastes. Table A has been created to better illustrate potential savings of improved storing and handling of raw materials.

Table A
Storage and Handling Procedures

ITEM	VARIABLE	EXAMPLE	YOUR FACILITY
A	Quantity disposed per year (gallons)	15	
B	Disposal cost per gallon	$5.45[a]	
C	Quantity purchased as replacement	15	
D	Purchase cost per gallon	$20.00	
E	Current operating costs = (A x B) + (C x D)	$381.75	
F	Initial time spent (hr)	8	
G	Employee wages per hour	$10.00	
H	Implementation cost = F x G	$80.00	
I	Continuing time spent per week (hr)	1/2	
J	Yearly pollution prevention costs = I x G x 52	$260.00	
K	Potential yearly savings = E - J	$121.75	

[a] Based on disposal cost of $300/55 gallon drum

Inventory and Purchasing - Photoprocessing Material and Ink

Costs associated with implementing improved inventory and purchasing practices involve staff time and training for initial inventory analysis and product usage review, inventory tracking, establishment of a proper stocking program (newest product placed behind oldest product). Good inventory management will achieve an estimated 10 to 20 percent savings in product purchase costs. A formula to determine the costs of a manual inventory system is found in Table B.

Table B
Manual Inventory System

ITEM	VARIABLE	EXAMPLE	YOUR FACILITY
A	Quantity disposed per year (gallons)	75[a]	
B	Disposal cost per gallon	$5.45[b]	
C	Quantity purchased as replacement	75	
D	Purchase cost per gallon	$20.00	
E	Current operating costs = (A x B) + (C x D)	$1,908.75	
F	Time spent learning inventory system, initial inventorying (hr)	40	
G	Employee wages per hour	$10.00	
H	Implementation cost = F x G	$400.00	
I	Continuing time spent doing inventory per week (hr)	1	
J	Yearly pollution prevention costs = I x G x 52	$520.00	
K	Potential yearly savings = E - J	$1,388.75	

[a] Assuming 500 gallons/year is purchased and 15% is wasted because of poor inventory controls
[b] Based on disposal cost of $300/55 gallon drum

Computerized inventory system cost and applicability are relative to each business situation. Complete systems that do estimating, manage customer files and history, plan print jobs, conduct production analyses, billing, invoicing, and inventory range from $75,000 to $300,000. Basic systems with estimating and inventory capabilities may cost from $7,500 to $12,500.

Improved Processes - Photoprocessing

The cost and efficiencies of equipment such as automatic film processors, replenishment systems, water flow and heat controls, and rinse bath agitators vary widely. Table C has been created to provide some degree of comparative information when evaluating pollution prevention alternatives.

Table C
Photoprocessing Methods

Method of Application	Capital Cost	Process Complexity	Waste and Emissions	Additional Considerations
Conventional tray processing	Low	Low	High	Variability in processed film quality
Automatic processor	Medium / High	Low	Low / Medium	Consistency in processed film quality
Automatic processor with chemical monitoring/ replenishment	Medium / High	Low	Low	Reduces photoprocessing chemistry consumption

Procedural changes such as countercurrent rinsing, closing chemical containers, to reduce product oxidation are relatively inexpensive and are compared in Table D.

Table D
Procedural Changes for Photoprocessing

Method of Application	Capital Cost	Process Complexity	Waste and Emissions	Additional Considerations
Countercurrent rinsing	Low / Medium	Low	High	Space required for tanks and installation cost
Closing chemical containers	Low	Low	Low / Medium	Easy
Add marbles	Low	Low	Low	Easy

Silver recovery from fixer solutions is an excellent pollution prevention option that many printers have adopted. The economics and efficacy of silver recovery systems vary based on factors specific to each business. Some of the factors are: method of silver recovery and removal, efficiency of the recovery unit, operator experience in processing film, type and quantity of film processed, and type of fixer used. Table E will help to conduct an initial analysis of the cost and benefits of each method of silver recovery.

Table E
Silver Recovery Methods

Method of Application	Capital Cost	Process Complexity	Waste and Emissions	Additional Considerations
Off-site recycling by a silver recycling service	Low	Low	High	Large quantities of hazardous fixer will accumulate on site and may affect hazardous waste generator category, fees charged by service can be high, replacement fixer must be purchased
On-site recycling: Electrolytic	Medium / High	Medium / High	Low	Recovers almost pure silver flake, silver can be sold, desilvered fixer can be reused, disposed fixer may require a "tailing" system to remove silver from fixer to discharge levels
On-site recycling: Metallic Replacement	Low	Low	Low / Medium	Recovers silver in sludge form, fee charged for further refining, fixer typically can not be reused due to high iron content, replacement fixer must be purchased, a series of canisters is needed to remove silver from fixer to discharge levels
On-site recycling: Ion Exchange	Medium / High	Medium / High	Low	Ion exchange is for removal of silver from rinse water, filters will require disposal and replacement and may be hazardous, additives and biocides must be added periodically, effective for high volumes of rinse water

Improved Processes - Ink

Many pollution prevention options involve in-house procedural changes, such as dedicating a press for one color or specialty colors to decrease press and fountain cleaning frequency, sequencing print jobs from light to dark colors, improved accuracy in job estimation, and presenting less hazardous alternatives to customers. These changes will require input and cooperation from press operators and management.

A computer controlled custom ink mixing system and digital scale involve capital expenditure and employee training. Table F lists some pertinent factors to consider.

Table F Computerized Ink Mixing System				
Method of Application	**Capital Cost**	**Process Complexity**	**Waste and Emissions**	**Additional Considerations**
Computer ink mixing system	Medium	Medium	Low	Low capital expenditure if existing PC can be used or upgraded, employees must be trained to used, digital scale required, can reduce ink inventory by 40-50 percent

MATERIAL SUBSTITUTION - INK

Petroleum-based inks emit high amounts of VOC's and are derived from a nonrenewable resource; therefore finding an adequate substitute is the primary pollution prevention option that will be investigated. There are many factors to consider when selecting an ink substitute such as type and age of press, printing process used, customer demand, and press operator expertise to name only a few. Table G compares major categories of ink substitutes.

Table G Material Substitution - Ink				
Method of Application	**Capital Cost**	**Process Complexity**	**Waste and Emissions**	**Additional Considerations**
Vegetable / Soy Ink	Low	Low	Low	Made from renewable resources, may cost 10 - 13% more, is very easy to recycle, black ink could be a problem
UVC	High	Medium / High	Very low	No VOC's, inks more difficult to recycle
EBC	Very High	Medium / High	Very low	Employee exposure to x-ray, cost up to $1 million for equipment, no VOC's, ink more difficult to recycle
Waterless Ink	High	High	Medium low	Waterless presses are very expensive (over $1 million), employee must be trained, low VOC's ink is not necessarily nonhazardous or less toxic

Electronic Technology - Desktop Publishing

In the past decade some printers had made the changeover to digital prepress technologies. Businesses have spent anywhere from 10's of thousands of dollars for simple front end systems to millions of dollars on complete systems with workstations, servers, imagesetters, and digital proofers.

Perhaps the most informative method to provide an overview of "going digital" is to present one small printers experiences with a changeover to digital technologies. The complete case study can be found in Pollution Prevention Manual for Lithographic Printers available from the Iowa Waste Reduction Center at 319-273-2079.

Case Study: Desktop Publishing

A small printer in Des Moines, Iowa, responding to increases in chemical and disposal costs, moved away from traditional typesetting and printing to desktop publishing.

Initially, the printer purchased a Macintosh computer and a laser printer, and tried to run a hybrid system with one desktop publishing system and four traditional Compugraphic typesetters. Once the boxes were opened, the printer knew he was in over his head, so he contacted a consultant to install the software and train his staff. Once the staff became familiar with desktop publishing, it became the system of choice, which made integrating both systems difficult. The time had come to make a choice: desktop or traditional. Encouraged by input from his employees, he chose desktop.

The printer secured a $23,000 loan to purchase three more computers and a second laser printer. He replaced the older model Macintosh with a newer, large screen model. With this equipment, he had desktop publishing stations capable of matching demand. He expanded his font library and his graphics capability increased dramatically. The consultant he had worked with previously agreed to set up the entire desktop publishing system and to conduct training for his employees.

The transition was difficult but, with help from the consultant, the business was running smoothly within three weeks. The consultant was invaluable in the transition, explaining the process and providing troubleshooting training for employees.

The printer is so pleased with the changeover to desktop publishing that he is seeking capital to expand current capabilities to include four more computers. Future plans include adopting technologies such as direct-to-plate to eliminate traditional photoprocessing.
The small printers advice to those who are contemplating desktop publishing: "Go for it" .... Find a good consultant, shop around, do not overlook universities, colleges, or community colleges...but hire the best consultant you can afford." Vendors of desktop publishing may also be able to provide installation, training and troubleshooting services.

The costs of going digital will vary ($15,000 - $40,000), but many printers are now making the transition successfully after thoroughly investigating several desktop publishing systems. The ultimate payoff will be in dollars gained in increased production and a decrease in toxic photoprocessing chemistry usage rates.

ELECTRONIC TECHNOLOGY - COMPUTER TO PLATE

A new technology is becoming more prevalent at larger businesses, metal computer-to-plate (CTP). The platesetter and other components of a complete CTP system do not necessarily offer any new products as was typical of digital prepress technology. To determine whether new technology such as CTP is worth investing in, a new set of financial benchmarks must be used, i.e., Net Present Value (NPV), Internal Rate of Return (IRR), Return on Investment (ROI) and Payback Period (PP). This financial jargon can be difficult to understand and even more difficult to use for the typical business person without the input from outside financial experts. Shops that wish to pursue this technology should already have sophisticated electronic prepress capabilities and be equipped for digital color proofing before taking the next step to CTP. One expert estimated that printers and trade shops should be prepared for a minimum $250,000 capital costs to move into CTP technology.