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Project Summary

Ink and Cleaner Waste Reduction Evaluation for Flexographic Printers

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The report summarized here describes the technical and economic effects that occurred when a flexographic label print shop changed the type of ink and cleaning agent used in the shop. The changes were undertaken as the best way to eliminate all hazardous materials. The company's management mandated the switch out of concern for its employees and with the intention of limiting possible future waste liability. Hence, the traditional alcohol-based inks and alcohol solvent cleaning agents gave way to water-based inks and an aqueous cleaner.

From a technical point of view, there is general agreement in this shop that the water-based inks yield better quality labels. Labor is reduced largely because the water-based inks are more easily removed from the pans, rollers, and plates. Ink splashes and spills are also quickly removed by sponging either with water or with the aqueous cleaner.

As a result of these process modifications, solvent emissions to the plant air have been reduced about 80%. The toxicity of the gaseous and liquid wastes has also been reduced approximately 90%. Hazardous liquid wastes have been eliminated while wastewater sent to the sanitary sewer has increased. Solid wastes have remained relatively unchanged.

The water-based inks brought about major savings because most of the liquid wastes do not now require disposal as hazardous wastes. The ink wastes are presently acceptable at the local public waste treatment plant. The cleaning towels and wipers are now either rinsed within the plant or sent to a commercial laundry; formerly, they had to be labeled as hazardous and segregated for special disposal. Though untreated ink washes are acceptable to the waste treatment plant, the company has chosen to filter theirs through a special absorbent to remove all color. The used absorbent is acceptable in the local landfill.

For this company, these changes involved no capital expenditures other than the absorbent unit. With the levels of various alcohols evaporated during printing now greatly reduced, the employees enjoy a cleaner and healthier plant environment.

This summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the WRITE program demonstration that is fully documented in a separate report (see ordering information at back).

Introduction

A Waste Reduction Innovative Technology Evaluation (WRITE) (with the Illinois Department of Energy and Natural Resources [ENR] and the U.S. Environmental Protection Agency [EPA]) was designed to (1) quantitatively compare the volume and toxicity of any waste generated during printing and released as gaseous, liquid or solid waste before and after switching to water-based inks and a detergent cleaner and (2) determine the economic effect of modifying a traditional printing technology.

This project evaluated flexographic printing of labels in commercial quantities. The participating firm was a narrow-web flexographic printer, MPI Label Systems, Inc., of University Park, IL. MPI Label Systems' plant is in a modern, one-story, clear span building. Its printing capabilities are based on several narrow-web flexographic presses each capable of printing one to six colored inks.

Several years ago, management directed the company's eight plants to eliminate the use of all hazardous and toxic materials. The incentives included a desire to eliminate employee exposure to any liquid or gaseous hazards resulting from handling these materials and an equal desire to minimize the possibility of future litigation resulting from use of such substances.

The decision forced each plant to substitute water-based inks for alcohol-based inks, and at the same time, change from alcohol solvent cleaning agents to aqueous type cleaning agents.

Water-based inks were substituted for those formulated with alcohols since the water-based inks were already available on the commercial market. Implementing this change, however, required extensive cooperation between the ink manufacturer and the printing plant because of different printing conditions, changing customer requirements, and the paper stock requirements associated with the water-based inks.

Because water-based inks are easier to remove or clean with aqueous agents when wet, a terpene-type (d-limonene) cleaner was initially tried. Later, a dilute aqueous solution of detergent proved to be even easier to handle, odor free, and less expensive. As cleaning agents are introduced to the commercial market, MPI Label Systems routinely tests them to determine if they can improve their process and be even safer for the environment.

Printing Background

Most printing operations function in a similar manner. Ink of the desired color and viscosity is supplied to the printing press where a rotating roller continually removes a thin layer of ink from the reservoir. This thickness is carefully and precisely controlled. Ink is then applied to the printing plate, followed by transfer to the printing stock. In the case of flexography, the plate is flexible and is wrapped around a separate roller. Customarily, when printing labels, a continuous sheet of paper receives an ink imprint of the image on the plate. When more than one color is involved, a separate plate is used for each color; each plate must be in registration for all the colors to be properly placed and rendered.

Paper stock for most labels is a two-ply material. The top ply, on which the labels are printed, normally has its bottom surface coated with an adhesive that adheres to the silicone-treated top surface of the bottom ply. Immediately after the plate applies ink to the label stock paper, the web moves through a heated drying area (70°C for this plant's press). Each dry label is then pressured by a steel cutting die that physically severs the top ply of label stock but does not remove the label from the surrounding blank stock. Moments after a label is severed from the surrounding stock by the die cutter, the print-free waste paper stock is peeled away from the bottom ply and collected on a separate roll destined for incineration or a landfill. The labels, still adhering to the bottom ply, go to another roll and are processed for shipment to customers.

Waste Reduction

Wastes are generated at most stages of the printing process. Ink wastes result when the reservoir, the various rollers, and the printing plate are cleaned at the end of a run. Excess ink in the reservoir can be collected for reuse, but the other ink quantities removed during cleaning generally remain as waste. MPI Label Systems keeps a 50-gal barrel of water adjacent to each press. During cleanup when water-based inks are used, soiled parts and cleaning towels are rinsed in this water to remove ink residues. At the end of the week, barrels of rinse water are transferred to an ink splitting device that absorbs the various ink pigments on a cellulose-based porous material; the nearly clear filtrate passes through for disposal in the sanitary sewer, with permission from the local water treatment plant. The pigment-colored cellulose is accepted at the local landfill along with paper wastes from the print line. Some paper wastes accumulated during setup operations are unavoidable, although an experienced printer is usually able to minimize them. Exceptional amounts of waste labels are, however, occasionally generated during the production of multicolor labels because of color registration difficulties. The adhesive-based, print-free stock surrounding each label is collected on a separate waste roll.

Most printing processes begin with a photographic negative. Developing the negative generates a number of chemical wastes that usually require special treatment for either recycling or disposal. The photographic chemicals used in producing the master negative account for small amounts of waste, though the silver is usually recovered. At least for flexography, the plate is developed after exposure to a bright light and by washing away the unexposed areas with a solution.

In nearly every step of the printing process, some volatile chemicals are released into the air. In some cases, this occurs as a result of process design; in other instances, it occurs simply because of the volatile nature of the materials. These volatiles can range from water to various alcohols, plastic thickeners, homogenizers, and chemical diluents. Each ink loses volatile material as a result of storage in the open ink reservoir; during rotation on the various rollers that determine the film thickness to be applied to the plate; as lost material on the plate; and during the heated drying phase. The ink ultimately reaches a rub-off-free state after the material on which it is printed passes through the heated drying zone. In addition to volatile losses associated with the inks, adhesive and solvent molecules evaporate from the adhesive-coated label surfaces as a result of simple exposure to the air. As with many chemicals, only a few molecules per cubic meter can, in some cases, create breathing distress for hypersensitive individuals, and the sensitive individuals must leave the contaminated area. Cleaning agents used on the press will also evaporate into the air. These cleaning solvents can range in type from water with small concentrations of detergents to various organic chemicals.

Procedure

The project compared the volume and toxicity of any gaseous and liquid wastes produced by the printing process before and after switching to water-based inks and an aqueous cleaner and then determined the economics of such process changes.

Laboratory measurements estimated the solvent loss from the inks by measuring the portion of the inks that evaporate and the materials used in the plant and by basing the calculations on the composition of the inks. Laboratory measurement of solvent loss by evaporation for each ink was used to estimate the percent volatiles. The amount of ink on waste labels was estimated by subtracting the total number of labels printed from the number of labels acceptable as product. These results were compared with the weight of volatiles in each ink as reported on the material safety data sheets. The alcohol-based ink contains six volatile components; four of them are alcohols, and ethyl alcohol and isopropyl alcohol are present in the largest amounts. By comparison, the water-based ink contains four volatile components, with most of the volatiles being water (65%) and isopropyl alcohol (5%). Some of the water, about 24%, is bound to the resins and does not evaporate on drying. Both the solvent cleaner previously used and the new detergent cleaner contain over 97% volatiles; again the detergent cleaner is mostly water. The amount of ink and other materials disposed of as liquid waste was determined gravimetrically, using a special rotating apparatus that exposed a continual and new thin film of ink to a constant, low-pressure air jet while the entire apparatus was kept at 70°C, for two printing runs. This approach minimized burning, charring, or spattering of ink as its viscosity continued to increase during solvent evaporation. This particular test was run in triplicate; samples achieved constant weights, ± 5 mg.

Results

Emissions from Inks and Cleaners

Because MPI Label Systems no longer uses alcohol-based inks nor permits them in the plant, the actual emissions of these inks during in-plant runs was not measured. The percent solids in each ink (and indirectly, thereby, the amount evaporated) was determined gravimetrically in the laboratory. These measurements (Table 1) indicate the proportion of the alcohol-based ink that evaporated was 48% compared with 56% to 62% for the water-based inks.

To estimate emissions that would have resulted from using solvent-based inks, it was assumed that the same amount of solids (or ink retained on the labels after drying) would have been used for printing the labels with alcohol-based inks as was used in printing with water-based inks. Then the total amount of ink that would have been used and the weight evaporated were calculated by using the percent loss factor determined in the laboratory. Since a smaller percentage of alcohol-based ink was lost to evaporation, more solids per gram of ink would be applied to the labels than with the water-based ink. Thus, less total alcohol-based ink was assumed to be used and less total weight of components would be lost via evaporation. The in-plant measurement results are shown in Table 2. The water-based inks-use data were obtained during two evaluated runs: One run was approximately 55,000 labels; the other about 250,000. In each case, the total weight of ink materials added and the weight of materials remaining at the end of the run were measured. The difference was the weight of material that was assumed to be either evaporated to the shop air, dried on the labels, or wasted. The portions evaporated and retained as solids were calculated with the use of the laboratory data presented in Table 1.

The press operators at MPI Label Systems estimated that about the same total amount of either ink is required for a job. Thus, this emission analysis is conservative for the alcohol-based ink. For comparison, the volume of alcohols evaporated during a printing run was calculated from the known formulations based on the total amount of ink used during each printing run. The laboratory evaporation loss results also agree quite well with the total volatile component data shown on the material safety data sheets.

Concentrations of each volatilized component in the plant air were calculated based on the volume of air in the shop area and the air exchange rate (Table 3). These concentrations are the levels expected during continual operation of the press assuming all six print stations are being used to apply ink. Ammonia and dimethanolamine levels were highest for the water-based inks. For the alcohol-based inks, isopropyl alcohol, methyl alcohol, n-propyl alcohol, ethyl alcohol, ethyl acetate, and Varnish Makers and Painters (VM&P) naphtha levels were higher.

Table 1. *Weight Loss Data from Laboratory Evaporation at 70°C*

Material	Initial wt., gm	Average of triplicate runs: Dry wt., gm	Wt. loss, gm	Std. dev., gm	% Loss
Water-based black ink	12.17	5.30	6.87	0.42	56.5
Water-based green ink	12.05	5.04	7.01	0.21	58.2
Water-based purple ink	12.22	4.66	7.57	0.20	61.9
Alcohol-based black ink	15.38	7.99	7.38	0.60	48.0
Detergent cleaner	12.56	0.28	2.22	0.03	97.8

Liquid Wastes

The amount of liquid wastes generated from printing with the water-based inks was measured during the two printing runs. These wastes (consisting of ink left in the reservoir, and on rollers, gaskets, and plates) were produced during cleanup at the end of each run. For the green labels, 24.6 g of ink and 44.3 g of cleaner were used. A more experienced operator only produced 56.4 g of liquid waste from printing the purple labels.

The concentration of ink and cleaner components estimated to be present in the wastewater from the facility (before treatment) is shown in Table 4. These concentrations were estimated assuming that each day the ink pans were all in use and cleaned out into a 50-gal tank, every week the tank was discharged, and most of the waste resulted from use of the cleaners. From the water-based inks, over 85% of the liquid waste was water. Other constituents of concern were acrylic resin, azo pigments, and isopropyl alcohol. Concentrations of constituents from the alcohol-based inks, if they had been disposed of in the same manner, were estimated to be much higher. Toluene, isopropyl alcohol, acetone, resins, pigments, and ethyl alcohol were the major constituents of concern.

Before implementing the use of water-based ink and detergent cleaner, the solvent-based waste ink was disposed of as a hazardous waste and was thus manifested. No liquid ink wastes were sent to the sanitary sewer before the use of water-based inks. Although the total amount of liquid solvent-based waste manifested in a year was on company records, this information was considered proprietary and was not made available for the purposes of this project. It was not possible to directly measure the amount of alcohol-based ink and cleaner wastes that would have been generated from printing runs similar to those evaluated with the water-based inks. Company officials reported that in their experience, the amount of solid and liquid wastes generated are es-

Table 2. *In-Plant Ink Use and Estimated Emissions*

Measured	Green Labels		Purple Labels	
	Water-based ink	Alcohol-based ink	Water-based ink	Alcohol-based ink
Total ink used,	1459	1175	399.2	293.1
Ink solids on labels,	609.8	609.8	152.1	152.1
Weight evaporated, g	849.1	565.2	247.1	141.0

Table 3. *Estimated Concentration of Air Emissions, µg/L*

Components	Purple Labels		Green Labels	
	Water-based ink	Alcohol-based ink	Water-based ink	Alcohol-based ink
Isopropyl alcohol	5.3	7.3	6.0	9.2
Ammonia	1.1	-*	1.2	-
Dimethyl ethanolamine	1.1	-	1.2	-
Water	58	-	62	-
Methyl alcohol	-	3.3	-	4.1
n-propyl alcohol	-	4.5	-	5.6
Ethyl alcohol	-	15	-	18
Ethyl acetate	-	2.9	-	3.6
VM&P naphtha	-	4.6	-	5.7

* Not applicable.

sentially the same for both ink types. The main difference, however, is that liquid wastes from the water-based inks did not have to be disposed of as hazardous wastes for this project.

Evaluation of Changes in Toxicity

Toxicity reduction evaluations for the ink and cleaner wastes were accomplished with the Degree-of-Hazard scheme developed and used by the Illinois Hazardous Waste Research and Information Center. The equivalent toxic concentration was calculated for four printing scenarios: (1) green alcohol-based ink with solvent-based cleaner; (2) purple alcohol-based ink with solvent-based cleaner; (3) green water-based ink with detergent cleaner; and (4) purple water-based ink with detergent cleaner. For estimated emissions to the air, the alcohol-based inks and cleaners had relative toxicities about 10 times higher than those for the water-based emissions. The same reduction was found in the liquid waste comparison. In actuality, no liquid wastes were discharged to the sewer when the company was using alcohol-based inks and cleaners. Therefore, the relative toxicity of these wastes increased from zero. Offsetting this is the fact that the undiluted alcohol-based wastes were previously sent to a landfill in the waste-containing drums.

Economic Analysis

The approximate annual savings at MPI Label Systems resulting from the ink and cleaner change is estimated by the plant manager to total at least $16,500 (Table 5). There is essentially no difference in raw material costs for the inks and cleaners. The overall productivity of the plant has increased, but the economic value of this increase could not be determined. Annual waste disposal and handling account for at least a savings of $15,000. The facility saves about $500 each year because of a lowered insurance premium based on improved working conditions. Savings because of new wiping materials (nondisposable) equals about $1,000 annually.

Conclusions

The results from the change to water-based ink and cleaner at MPI Label Systems are both definite and significant:

- Solvent emissions to the plant air have been reduced by at least 80%.
- Toxicity of these emissions has gone from potentially hazardous to humans to essentially harmless.
- Solid waste generated and destined for local landfills has been noticeably reduced in volume and is no longer classified as hazardous. This waste is mostly bulk paper for which a recycling system is being sought.

Additionally, these changes neither incurred capital costs nor increased operational expenses. Rather, the plant annually enjoys a significant saving associated with reduced waste disposal, insurance, and cleaning material costs. The shop manager at MPI Label Systems contends that associated benefits include

1. Water-based inks are easier to clean from pans, plates, and rollers when wet.
2. Water-based ink waste is more easily disposed.
3. Water-based ink spills are easier to clean up when wet.
4. Waste going to a landfill is no longer classified as hazardous, reducing MPI Label Systems' long-term liability.
5. Expensive solvents are not required for cleaning.
6. Employees are enjoying a cleaner, safer work environment.
7. Customers are receiving a better product.
8. Corporate concerns regarding hazardous materials are minimized.

The full report was submitted in fulfillment of CR-815829 by Illinois Hazardous Waste Research and Information Center under the sponsorship of the U.S. Environmental Protection Agency.

Table 4. *Estimated Concentrations of Components in Wastewater, μg/L*

Components	Purple Labels Water-based ink	Purple Labels Alcohol-based ink	Green Labels Water-based ink	Green Labels Alcohol-based ink
Isopropyl alcohol	159	344	317	687
Ammonia	26.6	-*	52.8	-
Dimethyl ethanolamine	26.6	-	52.8	-
Water	2090	-	4230	-
Resins	2.4	713	1290	1510
Pigment	1.0	713	528	1510
Methy alcohol	-	159	-	291
n-propyl alcohol	-	211	-	423
Ethyl alcohol	-	690	-	1400
Ethyl acetate	-	132	-	264
VM&P naphtha	-	211	-	423
Toluene†	-	6370	-	6370
Acetone†	-	2350	-	2350
Isopropyl alcohol†	-	2350	-	2350
Diacetone alcohol†	-	634	-	634
Water†	44.3	-	11700	-

* Not applicable.
† Constituents of cleaners

Table 5. *Economic Summary of Savings Using Water-Based Inks and Cleaners*

Parameter	Savings
Water-based inks	
Printing speed	Approximately 10% faster
Raw Materials	None
Waste disposal and handling	Minimum annual savings = $10,000
Aqueous cleaners	
Disposal	Minimum annual savings = $5,000
Raw materials	None
Overall Savings	
Insurance liability	Approximately $500/yr
Inventory	None
Wiping materials	Annually at least $1,000
Annual total	At least $16,500

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The complete report, entitled "Ink and Cleaner Waste Reduction Evaluation for Flexographic Printers," (Order No. PB93-191286; Cost: $17.50, subject to change) will be available only from:
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