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Project Summary

Replacement of Hazardous Material in Wide Web Flexographic Printing Process

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The study summarized here evaluated, on a technical and economic basis, the effect of substituting water-based inks for solvent-based inks in a flexographic printing process.

To reduce volatile organic compound (VOC) emissions by switching from the use of solvent-based inks to water-based inks, several equipment modifications and a feedstock substitution were completed: dryer capacity enhancement, press roller modification, ink handling equipment upgrade and installation of an in-line corona treatment system. Water-based inks containing 72.5% less VOC were used in lieu of, and in conjunction with, traditional solvent-based inks.

The ink substitution reduced the emissions generated from the printing process. For each percent increase in water-based ink use, VOC emissions were reduced 14 lb. This was based on usage of about 2250 lb of solvent-based ink/wk, which caused a VOC emission of about 1570 lb. Typically, the substitution did not adversely affect product quality or non-hazardous scrap waste generation. The average reduction of 95% of liquid F003 waste from waste ink and cleaning solvents recorded during the study period resulted from operational practice changes and employee training.

To complete the economic evaluation, the costs of press modifications, ancillary equipment, waste disposal, inks, and solvent were obtained. A payback period and project net present value were calculated.

The project has a positive net present value of $39,165 and a payback period of 2.5 yr, based on 21% utilization of water-based ink. If full conversion to water-based inks is implemented, the payback period is theoretically reduced to 0.54 yr.

Additional benefits from reduced VOC emissions and liquid hazardous waste have been an improved working environment: reduced indoor air pollutants, reduced handling of hazardous solvents by employees, and the appreciation by company employees of the need to make a conscious effort to further reduce waste generation.

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

A wide web flexographic printing firm substituted water-based inks for solvent-based inks when manufacturing flexible packaging using plastic sheet substrates (e.g., plastic bags for bread). The project objectives were to evaluate the technical feasibility (particularly as related to process implementation and performance), the economic effect, and the resulting change in VOC emissions achieved by the substitution. The technical evaluation was to quantify the reduction in both volatile and liquid-phase solid hazardous wastes.

This is a study of the effectiveness and applicability of ink substitutions to reduce waste in a wide web (greater than 16 in. wide) flexographic printing process. This Project was completed under the Erie County/EPA Waste

Reduction Innovative Technology Evaluation (WRITE) Program as a joint effort by Lustreprint Company; Erie County Environmental Compliance Services, Buffalo, New York; Recra Environmental, Inc., Amherst, New York; and the U.S. Environmental Protection Agency's (EPA) Office of Research and Development, Cincinnati, Ohio.

Procedure

The industrial participant (Lustreprint Company) prints flexible packaging whose products are used in the food and snack industry and in medical, industrial and consumer applications. Printing is completed on a number of different web materials, (commonly polypropylene (acrylic coated, Saran coated, and uncoated corona pretreated), cellophane (Saran coated), polyester (both metallized and unmetallized), polyethylene, and nylon (both Saran coated and uncoated)). At the time of this study, Lustreprint used one Hudson/Sharp 48 in., central impression, six-color, flexo press and one Heinrich (W&H) five-color, flexo, stack press.

In 1974, the New York State Department of Environmental Conservation (NYSDEC) approved a permit for air emissions from Lustreprint's two printing presses. When a three-shift, 7 day-a-week work schedule was implemented in 1989, the total plant emissions exceeded the baseline criteria of 100 tons/yr. of VOC's.

New York's regulations require that a facility reduce overall plant emissions to within the compliance level of 100 tons/yr. As an option, Lustreprint chose to reduce the use of solvent-based inks and adhesives. The first step eliminated solvent-based adhesives used in laminating. This was followed by a phase-in of water-based inks to replace the existing solvent-based inks in the printing operation. The company goals are to reduce all volatile organic air emissions to an extent that would eliminate the need for costly air abatement and permitting and to eliminate all liquid-phase solid waste, characterized as hazardous waste, at the facility.

To achieve these goals, ink use was monitored over four 1-wk-long study periods: 3-wks when both water-based and solvent-based inks were used and 1-wk when only solvent-based inks were used. Historical data for emissions and waste generation were extrapolated for comparison with the weekly experimental data. From the 4-wk ink use and waste analysis data, the VOCs, released as emissions from the printing process, could be calculated. A material accounting approach was used for these calculations. All liquid wastes generated during the test periods were segregated and analyzed for percent volatile constituents.

Substituting water-based inks required press modifications. The most significant retrofit was the installation of an Enercon corona discharge treater. Modifications to the Hudson/Sharp 48 in., central impression, six-color, flexographic printing press included upgrading drying capacities and using enlarged exhaust and supply fans. Additional ductwork and noise abatement equipment were needed. Ink metering rolls were replaced to facilitate drying. Pumps were also replaced to accommodate the new printing inks. Because of prohibitive costs, the Heinrich (W&H) press was not modified or retrofitted and was not used in the water-based ink tests. Future plans would include replacing this press with one that could accommodate the ancillary equipment required for water-based ink use.

The four 1-wk-long study periods were completed to acquire the information on ink use. Routinely, during the course of each week, several printing jobs were completed according to customer demand and work schedules. The type and amount of ink used for each printing job was recorded on a Job Ink Use Work Sheet and a Daily Operations Report Form. These forms were completed at the end of a print run by the press operator. Both ink use and make-up solvent added were recorded. This information was processed by a computer billing system to provide a total picture of the printing job with respect to material use. Information on the forms was transferred to the WRITE Ink Usage Report identifying ink stock number, ink type (water versus solvent and color), pounds of ink to press, pounds of make-up added, pounds returned to inventory, and weight percent VOC in the ink. VOCs were then calculated on a material balance basis.

Results and Discussion

Historical Background

Lustreprint is required to submit to NYSDEC, a monthly report describing VOC emissions from the plant as a result of operations. This information includes the amount of ink used with the necessary calculations to determine total VOC for the month. NYSDEC uses the information to determine regulatory compliance.

Historical data for the period April through August of 1990 was chosen for comparison with WRITE data for several reasons. Because three-shift work schedule adopted at this time provided comparable ink usage and the corona treater and other equipment had not yet been installed for the changeover to water-based inks, the information represented a period of exclusive solvent ink use. The data also represented a period with no significant plant operation upsets, which may have affected ink and solvent use. The historical data, in its raw form, represents total VOCs from ink and makeup solvent use for each month from the two presses, with half the ink use attributed to each press. Therefore, the data were adjusted to represent VOC emissions from a single press (total VOC/2) for a 1-wk period (total monthly VOC per press/4) for comparison with the study period data.

The data in Table 1 shows the VOC emissions, as a function of ink use, based on historical data.

Table 1. *VOC Emissions Based on Ink Use, 1990*

Month	*Ink used (lb/wk)*	*VOCs calculated (lb/wk)*
April	*3,038*	*2,111*
May	*1,681*	*1,700**
June	*2,686*	*2,289*
July	*2,109*	*1,731*
August	*2,945*	*2,345*

** This value is derived from the historical operational data and attributed to high makeup solvent use during the event.*

Table 2 provides information on the total pounds and percent of ink used, calculated VOC emissions, and VOC emissions as a percentage of ink used for each of the four 1-wk-long evaluation periods.

During Weeks 2 and 3 of the study, Lustreprint's quality assurance check sheets for each printing job were collected. The press operator checks the printing quality for several parameters at the start and during the press run.

Ink color, print position, and register are checked to ensure a satisfactory product that meets customer criteria. The ink adhesion check includes the industry standard 610 Tape Test. A tear sheet sample is collected and the print itself is checked for various printing imperfections such as pin-holes, halo, fish eyes, and roll marks.

A review of the quality assurance sheets indicates that the use of water-based inks typically did not change product quality although some problems arose after customer use, depending upon the ultimate use of the packaging, what the package contained, and the means by which the packages were sealed. Heat and stress of the printed package material caused by the package folding and sealing process at times resulted in a loss of ink adhesion.

Some combinations of water ink and solvent ink were incompatible. Water inks did not provide a consistent opaque white for laminations to cover metallized films and resulted in "blocking" (or transfer of print) when printing on Saran-coated materials, especially cellophane. In most cases, however, depend-

Table 2. *Ink and VOC Emission Data for 4-Week Study Period*

Measured Parameter	Week 1	Week 2	Week 3	Week 4
No. of inks	23	32	33	22
Solvent ink (lb)	1,112	1,746	2,252	549
Water ink (lb)	1,251	508	0	688
Total ink (lb)	2,363	2,254	2,252	1,237
Solvent ink (%)	47.1	77.5	100	44.4
Water ink(%)	52.9	22.5	0	55.6
VOC emissions (lb) (calculated)	827.5	1,251.7	1,571.5	509.0
VOC emissions (%) (% of ink total)	35.0	55.5	69.8	41.1
Waste (lb)	55.6	20.0	0.0	0.0
Waste VOC content (lb)	54.3	4.7	0.0	0.0

ing on the surface printed, no difference was noted with the use of water-based inks.

Normal propyl alcohol added in small amounts (less than 1%) to prevent water ink foaming at the ink pan and to assist in ink wetting was beneficial. Variations of the pressure sensitive "stickyback" material used to attach the printing plates to the plate cylinder (solid versus cushioned stickyback) also enhanced printing solid plate backgrounds without pin-holing. The plate material may also have an effect. Photo polymer plates work well with water but are more expensive than rubber. Nylon plates are a possible compromise with a longer life than rubber plates.

VOC Reduction

Substituting with water ink reduced the emissions generated from the printing process. For each percent increase in water-based ink use, the calculated reduction in VOC emissions was 14 lb (Table 3).

As can be seen from Table 3, for Weeks 1 and 2, the VOC generation decreased in proportion to the percentage of water-based ink used. A 52.9% water-based ink use resulted in a 53.3% reduction in VOC emissions. Similarly, in Week 2, a water-ink use rate of 22.5% resulted in a VOC emission reduction of 23.4%.

For Week 4, the corresponding reduction in VOC emissions was less significant: a 55.6% water-ink use rate reduced VOC emissions only 43.3%. Total ink use for Week 4 was 1,237 lb of combined water ink and solvent ink. This amount is approximately half that was used during the other 3 wks of the study. The number of different inks used in Week 4 is, however, comparable with that used in Week 1. With the same number of ink changes at the printing stations and with each change requiring a cleaning before adding new ink, the amount of cleaning make-up solvent relative to total ink use is expected to increase. The contribution of VOC emissions from clean-up solvents reduced the overall effectiveness of VOC reduction by water inks.

Waste Reduction

Historically, 315 gal of solid waste was generated each month. This translates to approximately 1.5-55 gal drums or 424 lb/wk. Printing operations during Week 1 generated 55.5 lb of solvent-ink waste, and Week 2 generated 20.0 lb of water-based ink waste. Therefore, the net result in Week 1 was an 87% decrease from normal in solid waste generation (from 424 lb to 55.5 lbs); a 95% decrease in Week 2 (to 20.0 lb); and 100% elimination of solid waste generation in Weeks 3 and 4.

Note that much of this waste decrease can be attributed to factors other than the type of ink used. The WRITE Program evaluation and the use of the waste generation form increased awareness of press operators and deterred waste generation. This induced press operators to reuse solvent for additional cleaning or reuse in the solvent inks.

Economic Analysis

An economic analysis of the changeover from solvent to water-based ink is included as part of this project.

Fixed, variable, and overhead costs are affected by this substitution and are considered. Fixed costs include the purchase and installation of new equipment (primarily the Enercon corona discharge treater) and costs for replacing equipment ancillary to the central impression cylinder press, such as pumps, dryer upgrade, ink pans, etc.

Variable cost adjustments include the premium paid, or reduced cost, for water-based inks. Calculating the costs for all inks used during each of the 1-wk period produced an average cost per gal. It was anticipated that, with the premium paid for water-based inks, the cost per gal would be higher for the weeks when the greatest amount of water-based inks was used. Disposal costs were calculated by using the amount of waste solvent ink generated in gals and the most recent disposal cost figures provided by Lustreprint. (The cost of scrap product waste was, however, attributed to plant personnel being unfamiliar with the operation of the corona discharge treater. This waste was not included in the economic determination and should decrease over time.) Other variable costs included variations in labor hours and utilities.

Overhead costs also play a role in determining the cost savings. Items such as the time previously expended for regulatory compliance, insurance costs, employee equipment and safety training, and OSHA compliance were expected to be reduced as a result of removing hazardous waste from the shop floor. These potential cost savings were estimated from existing figures where available.

Based on these costs, payback period and net present value (NPV) were calculated (Tables 4 and 5).

The payback period could be further reduced by eliminating the solid waste disposal. With the complete changeover to water inks and the planned purchase of an ink splitter at approximately $8,000, an additional savings for solid waste disposal is possible. The payback period would then be reduced 0.53 year.

Reduced material handling and regulatory and training costs would lower this payback period further. It was not possible to quantify these during the study, and it is estimated that their effect would be minimal unless full conversion took place.

The positive NPV indicates the project changeover will favorably affect cash flows and will ultimately result in a cost savings.

This economic evaluation indicates that the decision to substitute the water inks for solvent inks was financially beneficial. To underscore the selection, a brief discussion of the alternative, installing an incineration unit to control plant emissions, is necessary. The estimated cost of a facility wide incineration unit varied significantly — between $200,000 and $1,000,000. In addition, the VOC content of the Lustreprint emissions would have been insufficient for proper operation of the incineration unit. A supplemental natural gas feed for the unit would cost approximately $45,000 per year. Furthermore, the potential for further regulatory restrictions in solvent use for the printing industry could affect the cost/use of this technology. (Note - the control technology has nothing to do with further regulatory restrictions.)

Conclusions

By installing an in-line corona treater, higher surface tension water-based inks could be

used. This, in turn, reduced VOC emissions approximately 72.5%, when compared with those for solvent. The water-based ink formulas contain about 20% solvent. For a process using a quantity of approximately 2250 lb of solvent-based ink (weekly), VOC emission levels were about 1570 lb. For every 1% increase in water-based ink use, VOC emissions were reduced 14 lb.

The substitution typically did not adversely affect product quality or nonhazardous scrap waste generation. Some changes in operating procedures were, however, necessary because of the nature of water-based inks. The average reduction of 95% of liquid F003 waste from waste ink and cleaning solvents recorded during the study period resulted from operational practice changes.

The payback period for the corona treater and equipment modifications is 2.56 years. Additionally, through segregation of wastes once full implementation of water-based inks is achieved, the payback period could be reduced to 0.54 years. NPV works out to a positive cash flow of $39,165 for this project.

This project has resulted in a double benefit to Lustreprint: they have reduced their VOC emissions and reduced process costs. This successful implementation of water-based inks in flexographic wide web printing should be considered as a VOC source reduction method for similar printing operations.

The full report was submitted in fulfillment of CR-816762-02-0 by Erie County Department of Environment and Planning under the sponsorship of the U.S. Environmental Protection Agency.

Table 3. *VOC Reduction*

Week	Total ink (lb)	Factored* VOC (lb)	Water ink (%)	Reduced VOC (lb)	Reduction (%)
1	2,363	1,772	52.9	827.5	53.3
2	2,254	1,634	22.5	1,251.7	23.4
3	2,252	1,633	0.0	1,571.5	0
4	1,237	897	55.6	509.0	43.3

*Calculated by taking 72.5% of the total ink quantity.

Table 4. *Payback Period*

Variable	Initial Investment	Projected Savings	Payback Period, yr
Current process revisions	$62,901	$24,587	2.56
Adding an $8000 ink splitter	$70,901	$34,887	2.03
Full water-based ink conversion	$62,901	$117,078	0.54

Table 5. *Net Present Value**

Depreciation Method	Initial Investment	Operation & Maintenance	Tax Savings on Depreciation	Savings on Ink and Solvent	NPV
Straight line	$62,901	$6,145	$15,461	$90,577	$36,992
Sum of years digits	$62,901	$6,145	$17,634	$90,577	$39,165
Double declining balance	$62,901	$6,145	$17,238	$90,577	$38,769

*Assumptions: 10-year life span; no salvage value; 10% discount factor; 40% tax rate; $1,000 per year O&M cost.

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The complete report, entitled "Replacement of Hazardous Material in Wide Web Flexographic Printing Process," (Order No. PB93-228 128/AS; Cost: $19.50, subject to change) will be available only from:

National Technical Information Service
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