INK AND CLEANER WASTE REDUCTION EVALUATION FOR FLEXOGRAPHIC PRINTERS

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NOTICE

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FOREWORD

Today's rapidly developing and changing technologies and industrial products frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency is charged by Congress with protecting the nation's land, air and water resources. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the use community.

This document present the results of an experiment conducted to quantitatively compare the volume and toxicity of wastes generated during flexographic printing and released as gaseous, liquid and solid wastes, before and after switching to water-based inks and a detergent cleaner, and the economic impact resulting from modification of a traditional printing technology.

E. Timothy Oppelt, Director
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ABSTRACT

This report describes the technical and economic effects incurred by a flexographic label printer who changed the type of ink and cleaning agent used in its print shop. The changes were incurred as the best way to eliminate all hazardous materials. The company's corporate 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 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 have also been reduced by approximately 90%. Hazardous liquid wastes have been eliminated while wastewater sent to the sanitary sewer has increased. Solid wastes have remained relatively unchanged.

From an economical point of view, major savings develop with water-based inks at the studied facility because the majority of the liquid wastes do not require disposal as hazardous agents. The inks are presently acceptable to this locations local public waste treatment plant, and 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.

These changes, at least for this company, involved no capital expenditures. With the levels of various alcohols evaporated during printing now greatly reduced, the employees enjoy a cleaner and healthier plant environment.

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The U.S. EPA and the Hazardous Waste Research and Information Center acknowledge Don Gray of MPI Label Systems who arranged the use of the printing presses for testing.

Fred Shapiro of the Flexographic Technical Association (FTA) and Gary Jones of the Graphic Arts Technical Foundation (GATF) are acknowledged for reviewing the drafts of this report.

SECTION 1

INTRODUCTION

GENERAL PROJECT BACKGROUND

This final report is part of the Illinois/EPA WRITE (Waste Reduction Innovative Technology Evaluation) Program. The project was done in cooperation with MPI Label Systems, University Park, Illinois, a narrow-web flexographic printing firm. The purpose of the project was to quantitatively compare the volume and toxicity of any waste generated during printing and released as gaseous, liquid and solid wastes, before and after switching to water-based inks and a detergent cleaner, and the economic impact resulting from modification of a traditional printing technology.

Two main modifications in the printing practices of this company were examined in this project:

1. Water-based inks were substituted for alcohol-based inks.
2. A detergent cleaning solution was substituted for alcohol solvent cleaners.

The work was a joint effort of MPI Label Systems; the Hazardous Waste Research and Information Center which is a division of the Illinois Department of Energy and Natural Resources, Champaign, Illinois; and the Pollution Prevention Research Branch of the U.S. Environmental Protection Agency's Risk Reduction Engineering Laboratory, Office of Research and Development, Cincinnati, Ohio.

All site testing was conducted in the University Park, Illinois printing plant of MPI Label Systems, Inc. The plant is one of eight operated by the parent corporation in the United States. The company specializes in narrow-web flexography to produce a wide variety of labels. MPI has been in operation at the current site since 1988, having moved from an older nearby location. Its facilities are housed in a modern one-story, clear-span building of about 15,000 square feet. Half of the building is used for storage of supplies, and the other half for administrative offices and actual printing operation. Several of the press lines have the capacity to print up to six colors per label. Each line is operated by an individual who is responsible for all steps of a complete label run under direction of the press room supervisor.

The opportunity to conduct this evaluation came about as a result of the parent corporation's 1988 decision to eliminate, as quickly as practical, every toxic and hazardous material then in use. Part of the motivation for this action was corporate concern for its employees, primarily due to daily exposure to ink alcohol fumes in the work area. Another concern was a desire to avoid future liability and litigation resulting from legislation, which might limit the use of chemicals.

The first step evaluated and the most significant, was the conversion to water-based inks from alcohol-based inks. A related development instituted primarily for technological improvements but which also reduces the amount of waste, was the substitution of plastic printing plates for the older type rubber printing plates. Water-based inks did not produce satisfactory images with rubber printing plates. The amount of waste is also reduced due to newer and better plates in operation.

The project's second step was to study elimination of alcohol-based press-cleaners. Before this change, the cleaner-and-ink soaked press wipers required classification and disposal as hazardous waste materials, which was a relatively expensive handling and disposal operation. Initial project plans included evaluating the potential of replacing the alcohol-based cleaners with a terpene-type (d-limonene) cleaner. However, just prior to commencement of the in-plant measurements, MPI began examining some of the new aqueous cleaning agents which had recently become available on the market. These ranged from standard industrial detergent cleaners to newly-formulated terpene-surfactant solutions. This aspect of their operation continues to be one of periodic reevaluation as more satisfactory cleaners become available. Although MPI Label Systems now does its press cleaning with a single dilute aqueous solution of detergent (this is the cleaner examined), it is prepared to test any promising product.

PRINTING PROCESS BACKGROUND

The Printing Industries of America estimates approximately 57,000 printing, publishing and related facilities now operate within the United States. Of these, about 40,000 are commercial printers. The remainder according to a discussion with the Printing Industries of America include newspaper and magazine publishers, photocopiers and in-house printers (January 22, 1991). The five most common printing processes in order of their market share and volumes of ink used are lithography (also called offset), gravure, flexography, letterpress and screen (1). Flexographic printing derives its name from the flexible, roll-mounted printing plates characteristic of the system, as opposed to the less-flexible metal printing plates traditionally used in other printing methods. Presses are also categorized according to whether they print on individual sheets, called sheet-fed, or on a continuous roll, called web, of paper or other substrates.

The most recent industry survey by the Flexographic Technical Association (FTA), 1989 states that over 4,000 U.S. printing plants utilize more than 22,000 narrow-web flexographic presses (2). These plants employ about 150,000 individuals, and generate about $4.5 billion annually of product. Annual growth rate during the past decade is estimated to have been 3% - 5%.

The 600 year old printing technology follows certain well-defined steps. It begins by deciding to reproduce an image, whether text or illustration. The substrate upon which the image is to be reproduced must be selected, (e.g. paper, cardboard, plastics, fabric, metal, glass, etc.). That substrate must then be obtained in adequate quantity and quality. The color of the image to be reproduced requires that suitable inks be secured. Depending upon the particular printing process, the ink must be formulated to have an acceptable viscosity, or rate of flow, and the correct color imparted to it by resident pigments. The latter are usually opaque, insoluble materials, finely ground to submicron size before being incorporated into the mixture. Pigments are usually soluble colorants that are used to color fabrics, water colors, and some stains.

The image to be reproduced by printing must be developed into a form, usually called a plate, suitable for printing. If the image is to be printed in only one color (black ink on white paper, for example), then only one print image needs to be made. For each color needed, an additional print image is necessary. These images are made by various processes on various types of metal, wood, stone, rubber or plastic plates. Originally, most print faces or plates were carved by hand, and special art work is still done that way.

Within the printing industry, the most common plate making process begins with a photographic negative of the image to be reproduced. For some printing processes the photo negative can be placed directly on the photosensitive material intended to constitute the finished plate. This material sandwich (negative on plate material) is exposed to an intense light during which the exposed portions (those beneath the clear areas of the negative) of the plate will harden and be impervious to the washing inherent in the development process. Any unexposed areas are dissolved by a plate developing solution.

Once an acceptable printing plate is approved by the customer, it is positioned in the printing press, usually by forming around a roller. Ink of the proper color in a reservoir is made continually available to a series of rollers which forms an ink film of the proper thickness for application to the plate. The ink on the plate is eventually transferred to whatever substrate is being used. If more than one color ink is required then each color will be applied sequentially. The ink dries in place, either by evaporation, absorption, oxidation or polymerization of its oils and solvents, after which the final printed product is readied for distribution. The common printing processes described previously accomplish each step in different ways. However, regardless of the different printing processes and different intermediate steps utilized by the printer, the final results tend to be much the same.

Figure 1 is a simplified schematic of a single flexographic print station. Ink in the reservoir is picked up by a roller. The roller contacts at least one additional roller to develop an evenly distributed ink film of ideal thickness for transfer to the plate which will make impressions of the first image. The substrate paper in this study is pressed against the printing plate by another roller to ensure the plate's ink impression will be uniform. Rollers are used so the entire process can be continuous. After passing through each station, the newly printed materials move into a drying station. In a matter of seconds, the ink dries. Each station contains heaters to maintain a temperature of approximately 70°C.

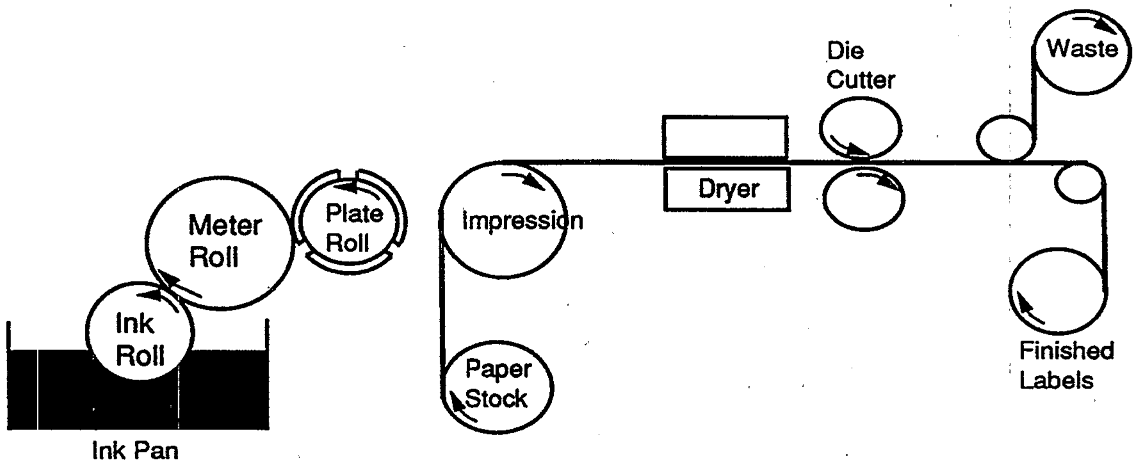

Figure 1. Single print station schematic for flexographic printing

The printing station shown in Figure 1 is limited to a single color ink. Multicolor printing simply places additional printing stations in series, each station applying a different color. These printing stations are referred to collectively as a single printing press.

Depending on the type of material receiving the plate's impression, and the customer's desire, the dry printed surface may be coated with a gloss varnish or plastic to protect it in the last station. After the final station, and separation from the excess material around the printed area, the completed labels are wound onto a roll. The speed at which paper is fed through the press can be varied, depending on the label size, ink type, precision of the press and skill of the operator.

Within the flexographic printing industry, press types are classified as narrow-web and wide-web. Narrow-web is typically used to print tags, labels and some packaging. Wide-web presses are used for envelopes, plastic bags, newspapers and wall paper.

Paper stock for printing labels flexographically, the popular system for printing labels in the United States is made of two-ply material (3). The bottom ply consists of silicone-treated paper. The top ply is the paper on which the labels are printed, and is adhered to the bottom ply. The top ply peels away from the silicone treated bottom ply. After printing and drying, each label is "parted" or readied for removal from the parent paper web. Each label's perimeter is cut-out by a steel cutting roller. The parting roller, working to very close tolerances, cuts through the single top ply of paper to separate the finished label from the surrounding unprinted stock. This stock waste is peeled away automatically onto a separate roll for disposal, usually by shipment to a landfill. The bottom ply, with adhering labels, is made up into rolls of a specific label count for each customer, then packed and shipped. Customers will remove and apply the finished labels either automatically or manually. The silicone-treated base ply, from which the labels are removed by the customer, is usually disposed of in a landfill or by incineration, according MPI Label Systems.

According to a discussion with the Graphic Arts Technical Foundation, typical flexographic ink incorporated the following: a resin, to provide adhesion and to help disperse the pigment; a solvent, to control viscosity and drying rate; a plasticizer, to soften the resin; occasionally a lubricant, to control the coefficient of friction; and a defoamer, to limit foam formation in the ink reservoir (December, 1989). Suitable resins for aqueous inks include shellac, soya protein, casein, acrylic copolymers, and emulsions of latex. Acceptable solvents are lower-molecular weight aliphatic alcohols, esters such as ethyl acetate, glycols, and, of course, water.

Finally, a pigment is added to provide the necessary color. Typical flexographic pigments are: titanium dioxide and kaolin clay for white; carbon black and ferrous oxides for yellow, red and black; various azo compounds for yellow and red; and phthalocyanine derivatives are valuable for blues and greens.

MPI Label Systems' water-based inks contain organic chemical pigments, an emulsifier (1%), an acrylic resin thickener (20%) similar to that found in water-based house paints, up to 5% of isopropyl alcohol, 1% of ammonia and 50% - 65% water. The inks used do not contain heavy metals.

Because the cleaning agents used most frequently by printers are often composed of organic solvents, the majority of wiping materials used as sponging pads are classified as hazardous waste and disposed of in hazardous waste landfills at a relatively high cost. At MPI Label Systems the fiber wipers, previously used with the alcohol based rags and cleaners, have been abandoned in favor of fabric shop towels which, after use, are laundered and reused, resulting in additional savings.

WASTE REDUCTION IN PRINTING

Printing produces waste at every step. Solid and liquid wastes generated in plate production include: damaged plates, developed film, photographic chemicals, silver (most printing operations recover the silver), and plate-developing solutions. Spent photoprocessing chemicals are generally regarded as being biodegradable and are usually discharged to the sewer. Depending on the specific materials used, some volatile solvents may also be released to the air as part of image making and plate processing.

During the printing process, volatile solvents in the inks (e.g., aliphatic alcohols and ketones, and aromatics) and cleaning solutions are released to the air. Most of the ink solvents are evaporated during the drying process, though some are absorbed by the treated paper surface. The type and amount of solvents released depends on the ink formulations and the area of surface printed. Point source control technologies such as catalytic or thermal incineration have been installed in some plants to capture solvent releases (4-7).

Waste inks diluted with cleaning solvents are the primary liquid wastes generated in the printing process. Most inks can be recycled, e.g. by blending to make a black ink. Waste inks that contain hazardous organic solvents must be classified as hazardous wastes and either incinerated or distilled to recover the solvent. Small amounts of lubricating oils are the other liquid waste that is generated from operation of the printing presses. This used oil has the potential to be recycled (5).

A wide variety of cleaning solutions are used by printers. These flexographic cleaners can contain volatile organic chemicals such as toluene and naphtha. In those cases where the solvents are absorbed on fabric towels for handling by a commercial laundry, it may be necessary for the printer to generate the documentation required for hazardous wastes, and the launderer will be required to provide the documentation required of a hazardous waste treatment plant. Consequently, finding suitable nonhazardous substitute solvents could save considerable effort and expense for both parties.

Waste paper is the main solid waste generated in printing. The paper consumed as waste during a flexographic label setup is largely a function of the press operator's experience and training, the accuracy of the artwork, and the condition of the press (i.e. number of inks required and size of the label). Operators try to use paper stock of such a width as to minimize trim waste. Other solid waste produced includes empty ink containers and cleanup rags or wipes. Some printers dispose of their rags in the trash while others have the rags laundered for reuse. The sludge produced in the rag cleaning process contains the materials removed including inks, cleaners, oil, dirt and other contaminants. This sludge almost always requires disposal as a hazardous waste (5).

Options for reducing waste generated by printers have recently been reviewed for three cases by the State of California and the USEPA (8,7). Methods for waste reduction in materials handling and storage, image processing, plate making, printing, and finishing have been listed. Techniques which can be used to reduce waste during printing include using less hazardous inks and cleaners, plus generally being more careful during setup and cleaning. Waste solvent-based ink was reduced in one case by spraying a protective coat over the ink in the reservoir at the end of each day. As a result, waste ink was reduced by five pounds per day. Thus, less waste ink would need to be disposed of and less new ink purchased. The total operating savings in this specific case were estimated at $3,375 per year for this technique (8). Spraying inks surfaces when not in use is a standard procedure in many shops. Techniques for reducing waste paper in web operations include installing break detectors and automatic splicers. Waste paper can never be entirely eliminated. An emphasis on recycling is also necessary. However, as noted in MPI Label Systems' case, the waste paper may have adhesives or other coatings that exclude it from reuse.

Changing to less hazardous inks is not always straight forward, though recent advances in formulations have overcome many limitations. Water-based inks theoretically require more energy to dry than solvent-based inks. This requirement has not been shown to be of any significance in this project printing on paper since the heater and drying chamber for each ink color is adequate to compensate for the additional energy requirements; however, this may be significant when printing on films and foils.

With modern water-based flexographic inks, many label types can be run up to 10% faster due to improved press design (i.e. dryers, etc.). Other reported limitations of water-based inks such as requiring more frequent equipment cleaning and tending to cause the paper sheets to curl have been overcome by improved formulations. Many water-based inks also have acceptable gloss but appear to be low-gloss due to absorption on the paper, though this can be overcome by using an overcoat or printing on a varnish undercoat. Another alternative which can reduce solvent emissions is the use of ultraviolet (UV) inks which set or harden when exposed to UV light rather than by evaporation. The disadvantages associated with UV ink include higher ink cost, the need for special equipment, exposure of personnel to UV light, and the toxicity of some of the ink chemicals. Electron-beam-dried inks are also available that contain no solvents, but operator protection from X-rays used in the process is required and the system often degrades the paper (5).

A case study of switching from alcohol-based to water-based inks on low density polyethylene film a flexographic printer was presented by Makrauer in 1987 (9). He reported considerable difficulty in making the conversion. Technical problems included pH control for the ink, a need to modify the drying equipment, ink metering modifications and increased roller wear. All problems were gradually overcome through improved ink formulations, experimentation, and facing the rollers with more durable materials. Makrauer also reported that cleaning water-based inks was more difficult. Benefits of water-based inks at that time were reduced air emissions, less toxic liquid wastes, improved color control, greater coverage yield, and improved working conditions due to reduced alcohol vapors. Quantitative measurements of emissions and other wastes generated when using alcohol-based inks compared with water-based inks were not reported. A discussion with the Flexographic Technical Associated on the quantitative evaluation of the benefits of using water-based inks in flexographic printing elicited their opinion that there probably are no significant economic advantages (March 1991). For example, both ink types cost about the same, and while some printers report faster printing is possible in some instances, others point out that presses must be slowed for some water-based materials. If there is an overwhelming economic advantage to be achieved with water-based inks, it will probably be due to the elimination of various hazardous wastes.

The introduction of water-based inks in printing on plastic materials via flexography had some early problems using the same technology for newspapers. The developments made by the newspapers have helped all flexographic operators. In several installations, the print line and ink supply lines have been designed to literally eliminate ink wastes. Excess ink and ink washings are collected in a holding tank and used to dilute new inks to the proper viscosity. This type of ink management is the same whether water-based or solvent-based ink is used at the facility. This closed-cycle system does not reduce the paper wastes, and relies on a continual demand for black ink. Although none of these newspapers have published an economic comparison of the old versus the new system, private discussions with plant managers confirm each plant is producing a better product at less cost.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The change from alcohol-based inks and cleaners to water-based inks and a detergent cleaner has resulted in less quantity and toxic waste being generated at MPI Label Systems. However, there were some trade-offs such as elimination of hazardous wastes but generation of wastewaters discharged to the sewer. As with most changes in processes, the switch in materials, including changing the type of plate used, required many adjustments and fine-tuning. Also, during the past two years advances have been made in the water-ink formulation so these inks are easier to clean, and the rate at which labels can be printed has increased. The cooperative approach developed between industry and government in this project, and the comparative methods, described in later text, can be used to evaluate the environmental and economic benefits of other similar product substitution projects.

The amount of solvent emissions to the air was reduced by over 80% per run as a result of changing inks and cleaners according to the measurement taken at MPI Label Systems. In addition, the components emitted (primarily water) are considerably less toxic to the press operators and the environment than were being emitted from the alcohol-based inks. Since MPI Label Systems uses approximately 1,800 pounds of ink per year, an estimate can be made of the total weight of solvent emissions they currently release and what would be released if they were still using the alcohol-based inks. This comparison is shown in Table 1 for MPI and by extrapolation to the entire flexographic industry in the United States.

TABLE 1. COMPARATIVE SOLVENT LOSS TO AIR FROM USING WATER-BASED INKS

Ink type	MPI Label Systems, Inc.	Entire Industry
Alcohol Inks	927 lbs/yr solvents	153,900,000 lbs/yr solvents
Water-based Inks	185 lbs/yr solvents	29,240,000 lbs/yr solvents
Total Solvent Reduction	787 lbs/yr solvents	124,660,000 lbs/yr solvents

For this estimate the laboratory evaporative loss percent for black ink, as determined in this study, was used. If the entire industry would require 300 million pounds per year of waster-based inks; then for the entire industry 125 million pounds per year of toxic solvents would no longer be emitted. Additionally, zero air toxics are being released from MPI Label Systems' new detergent cleaner as opposed to the hazardous material previously released from their solvent cleaner. Although hazardous wastes have been eliminated at MPI Label Systems, the total waste situation is not completely improved. For example, aqueous wash liquids discharged to the sanitary sewer have increased from the volume required for simple housekeeping and personal needs to at least an additional 7,800 gallons per year. Solid wastes generated in the form of wasted labels, wrap, trimmings and other paper have remained about the same.

The water-based inks were estimated, to reduce the relative toxicity of the liquid and air waste stream. A significant 10 fold reduction in the equivalent toxic concentrations for both the liquid wastes and air emissions was found compared to the alcohol-based products.

As a consequence of switching inks and cleaners, MPI Label Systems estimates an annual cost savings of at least $16,500 per year. In addition to the above dollar advantages accruing from use of water-based inks and a relatively harmless cleaner, it is the opinion of MPI Label Systems plant manager and shop superintendent that MPI Label Systems is also realizing the following subjective benefits:

1. Water-based inks are easier to clean from pans, plates and rollers;
2. Water-based inks waste is more easily disposed of;
3. Water-based inks spills are easier to clean up when wet;
4. Water-based inks waste material that is going to a landfill does not have to be classified by MPI Label Systems as hazardous, thus reducing long-term liability;
5. Water-based inks do not require expensive solvents for cleanup; and
6. Employees are enjoying a cleaner, safer work environment.

During the planning stages of this project it was intended to quantitatively measure ink and cleaner usage at every step of the printing process. After a preliminary run it became apparent that several of these measurements would be very difficult to carry out. Two examples are worth noting. First, it was intended to determine by weighing the amount of dry ink actually deposited on labels. This was to be accomplished by weighing approximately 1000 blank labels as they came from the press, and 1000 printed labels. After numerous measurements, at least for the labels measured, it became obvious that the amount of ink on anything but a very large number of labels is negligible. It appears that variations in the paper weight and, perhaps, non-uniform thickness of the adhesive film are much greater than the amount of ink applied. Second, the amount of ink wasted on the paper trimmed from around each label was to be measured. The trimmed top layer with adhesive backing is peeled away from its paper base, then collected as a roll of waste. Since each layer sticks to the preceding one it was not possible to separate individual layers of the trimmings from each other to weight an known number of trimmed labels.

The result of these two experiences was that the ink reservoir was weighed before and after a run and the difference was considered due to all ink uses - labels, trim waste, spills, cleanup of the ink pans, rollers and printing plates. With the exception of the ink lost during cleanup (and on a relatively short run this will represent most of the ink used) the balance will have lost its solvent content to the shop air.

A lesson learned during this project is the importance of a pre-testing agreement for all planned plant tests with the company personnel involved. In this case, prior to collecting in-plant measurements, several label runs were closely observed to learn the various steps, materials, etc., to be encountered. However, by the time measurements were taken, the plant had made significant changes in some of their procedures. MPI Label Systems staff continuously evaluate new inks, cleaners and other materials from vendors. Ink manufacturers are frequently improving their formulations. During a six month period, MPI Label Systems changed ink suppliers at least twice and evaluated several new cleaners. As better materials and less expensive procedures become available that will maintain or improve quality while reducing costs, almost any process change will be considered by this facility. Thus, the experimental plan had to be modified and the results including various cost factors were not static.

It should be kept in mind that the scope of this evaluation was limited in several important aspects. The image and plate making steps were not included in the evaluation of waste produced since the plates used at the MPI Label Systems plant are produced by another company. The wastes generated while formulating inks and cleaners were not comparatively evaluated, and the impact of using water-based inks on the recyclability of the product labels was not evaluated in this study.

MPI Label Systems and the entire flexographic printing industry are benefiting economically, in the quality of the printed product, and in employee health and safety by changing from solvent-based to water-based inks and cleaners. The environment is also benefitting. Additional benefits will be realized as the use of solvent-type industrial cleaners is increasingly phased out. Label customers are also benefiting from the change in technology with better quality labels being produced.

SECTION 3

METHODS AND MATERIALS

ON-SITE TESTING

Solvent loss by emission from the inks was estimated by a combination of approaches including materials use measurements during two print runs, laboratory measurement of alcohol evaporation from the two types of inks, and calculations based on the reported composition of the inks. The methods used to compare emissions from the two ink types are summarized in Table 2.

TABLE 2. METHODS USED FOR ESTIMATION OF EMISSIONS

Type of ink	Materials use in plant	Evaporative loss laboratory	Ink composition calculation
Water-based	X	X	X
Alcohol-based		X	X

Since MPI Label Systems no longer uses alcohol-based inks, and no longer permits their use, it was not possible to measure actual emissions during in-plant use of alcohol-based inks. However, the volume of alcohols evaporated from the two types of inks during a printing run can be calculated from known ink formulations if the total amount of ink used is known. In-plant measurements of ink and cleaner usage were taken for two single-color printing runs to obtain an estimate for variability.

For the materials balance method, the weight of ink used during each printing run, A, was calculated by weighing the various items before and after the printing runs using the following formula:

$$A = (B + C) - (D + E + F) \tag{1}$$

where B = weight of ink in reservoir and weight of reservoir at beginning

C = weight of water and other materials added during run

D = weight of ink remaining in reservoir and weight of reservoir at end of run

E = weight of ink retained in the ink pan, and on the gaskets, at end of run

F = weight of ink lost by spilling

Mass measurements were taken on an electronic balance (capacity: 12 kgs, ± 0.1 g) which was transported to the printing site. The percent solids, S, of both ink types and cleaners were determined gravimetrically in the laboratory by drying known weights in triplicate (approximately 10 - 15 grams each) of ink samples in a rotating device to maintain a thin ink film. The drying temperature was 70°C as maintained on each press. Then the percent of volatile materials, V, was calculated by simple subtraction:

$$V = 100 - S \tag{2}$$

Laboratory measurements of the percent solids, S, for each ink were used to estimate the total weight of ink, Q, retained on all the labels (acceptable and waste) working from the total weight of ink used, A, as follows:

$$Q = A \times S / 100 \tag{3}$$

The amount of ink on waste labels, G, was then estimated by the proportion of total labels printed, H, to good labels sold as product, K.

$$G = Q \times (H - K) / H \tag{4}$$

The weight of volatiles in each ink determined gravimetrically in the laboratory was compared with the values reported on the material safety data sheets. This information is shown in Table 3. Both inks have similar amounts of total volatiles. The alcohol-based ink contains six volatile components, four of them alcohols. Ethyl alcohol and isopropyl alcohol are present in the largest amounts. By comparison, the water-based ink contains four volatile components. Most of the volatiles are water and isopropyl alcohol. Some of the water is bound to the resins and does not evaporate upon drying. According to a discussion with the Flexographic Technical Association this amount of water is around 24% (March 1991). Both the solvent cleaner previously used and the detergent cleaner now in use contain over 97% volatiles. The volatiles from the solvent cleaner were hazardous while the detergent cleaner volatiles are nonhazardous. The relative compositions of cleaners tested as reported by the manufacturer are presented in Table 4.

The amount of ink and cleaners produced as liquid waste was determined gravimetrically for the two printing runs. No liquid ink wastes were sent to the sanitary sewer prior to using water-based inks. The alcohol-based waste ink had to be disposed of as a hazardous waste and thus manifested to a landfill. Currently these types of wastes can no longer be landfilled and are usually incinerated or recycled. While the total amount of waste manifested in a year is on company record, this information was considered proprietary and was not made available for the project. Nor was it possible (because of the company ban) to directly measure the amount of liquid alcohol-based ink that would have been used for 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 essentially the same for the two types of inks. The main difference is that liquid wastes from the water-based ink do not have to be disposed of as a hazardous waste.

Currently, each printing line maintains a 50 gallon drum of water for use in disposing of ink wastes. At the end of each printing run, the ink reservoirs are rinsed in these drums. Each drum is emptied every week into a commercial ink filtering device called an Ink Splitter. This unit absorbs the colored pigments on cellulose fibers, and the slightly grayish filtrate is run to the sewer, as approved by the local treatment plant. The colored absorbent is acceptable in landfills as non-hazardous material. The concentration of ink and cleaner components that would be in this facility's effluent was estimated assuming ink wastes on the press rollers, pans and plate are removed by scrubbing with a brush and fabric town wetted with an aqueous detergent solution. This quickly removed the ink residues. The rollers, pans and plates are then dried with another fabric towel. The towels are rinsed in the barrel of water at each press, then sent to an industrial laundry service for cleaning. By appearance, a negligible amount of ink was retained by these towel. The amount of detergent cleaner used was measured for each run (although this depends largely on the press operator's general practice), but it was not possible to measure the amount of solvent cleaner previously used. Therefore, it was assumed that the same amount of solvent cleaner would have been used as was consumed using the detergent cleaner.

TABLE 3. COMPOSITION OF INKS TESTED AS REPORTED BY THE MANUFACTURERS

Type of Ink	Component	Percent by weight
Alcohol-based	Methyl alcohol	04.7
	Isopropyl alcohol	10.6
	n-propyl alcohol	06.5
	Ethyl alcohol	21.4
	Ethyl acetate	04.2
	VM&P naphtha	06.6
	Resins	Unknown
	Pigment	Unknown
	Total Volatiles	54.5*
Water-based	Isopropyl alcohol	05.0
	Ammonia	01.0
	Dimethylethanolamine	01.0
	Acrylic Resin	20.0
	Azo pigment	08.0
	Water	65.0
	Total Volatiles	56.5*

* Both ink types contain plastic-based resins which react and bind with some of the other materials present on drying, including some of the volatile materials. Hence, one cannot simply add the volatile percentages to obtain total volatiles.

TABLE 4. COMPOSITION OF CLEANERS TESTED AS REPORTED BY THE MANUFACTURERS

Type of cleaner	Component	Percent by weight
Organic solvent cleaner	Toluene	54.5
	Acetone	20.0
	Isopropyl alcohol	20.0
	Diacetone alcohol	05.5
	Total volatiles	99.+
Detergent cleaner	Total volatiles	97.8

DEGREE-OF-HAZARD

Toxicity reduction evaluations on the ink and cleaner gaseous and liquid wastes were accomplished with the Degree-of-Hazard scheme (10). This is a method developed and used by the Hazardous Waste Research and Information Center and is not an EPA method or requirement. The Degree-of-Hazard is calculated utilizing the equivalent toxic concentration, C_{eq}, as follows (10):

$$C_{eq} = Y \times SUM\,[C_i / (B_i \times T_i)] \qquad (5)$$

where SUM = sum of the results of the calculation in parentheses for each component of the waste stream.

C_i = concentration of component i as a percent of the waste by weight

T_i = measure of the toxicity of component i

Y is a constant equal to 300. It is used to allow entry of percent values for C_i and to adjust the results so that a reference material, 100% copper sulfate, with an oral toxicity of 300 mg/kg, achieves an equivalent toxicity of 100.

B_i is a conversion factor used to convert toxicities, T_i, to equivalent oral toxicities. B_i is determined from Table 5. For carcinogens and mutagens, an oral rate TD_{50} is used when available. Otherwise, carcinogens are assigned a T_i of 0.1 mg/kg; and mutagens are assigned a T_i of 0.6 mg/kg. Toxicities are converted to equivalent oral toxicities as specified in Table 5. The equivalent toxicity given in Table 5 has the same toxicological response as referenced in the RCRA listing criteria (10).

Toxicity values are ranked by type according to the following priorities, with the preferred types listed first: oral rat, inhalation rat; dermal rat; or, aquatic toxicity and other mammalian toxicity values. If there is more than one value for the toxicity from the preferred available source, the lowest (most toxic) toxicity value is used. If a carcinogen is assigned a value for T_i in the absence of a TD_{50}, B_i is assigned a value of 1.00.

The overall toxic amount, M, of each waste stream is calculated as follows:

$$M = Z \times C_{eq} \qquad (6)$$

where Z = maximum size of waste stream produced, kg/month.

TABLE 5. TOXICITY CONVERSION FACTORS

Conversion factors for the equivalent oral toxicities B_i		
Toxicity measure	Units	B_i
Oral - LD_{60}	mg/kg	01.00
Carcinogen/mutagen - LD_{60}	mg/kg	01.00
Aquatic - 48 or 96 hr - LC_{60}	ppm	05.00
Inhalation - LC_{60}	mg/l	25.00
Dermal - LD_{60}	mg/kg	00.25

The result of these calculations will be an estimate of the relative toxic amount, M, of the gaseous and liquid wastes produced for each ink and cleaner type evaluated. This toxic amount takes into account the toxicity and amount of each component of the inks and cleaners. The toxic amount, M, can range from 0 to greater than 10,000. This toxic amount can ben considered a relative toxicity of each waste stream. The relative toxicities can then be compared for the air and liquid wastes produced while printing with the two types of inks and cleaners.

ECONOMICS

The economic analysis of these changes is based on the factors shown in Table 6. Monetary values are based on annual costs, the only valid approach since no capital investment was required; hence, such terms as annual rate of return and payback are not applicable. The factors listed in Table 6 were selected after a tour of the plant and discussions with the plant manager. Certain qualitative costs such as training of personnel, minor press modifications, cleanup time, compliance, and legal fees are not included since it is hard to associate a monetary value with these items.

TABLE 6. SUMMARY OF COST COMPARISON FACTORS EVALUATED

Material	Cost comparison factors
Inks	Raw materials
	Waste disposal and handling
Cleaners	Raw materials
	Waste disposal and handling
Overall	Insurance liability
	Inventory control
	Wiping materials

SECTION 4

RESULTS

ON-SITE TESTING

Two single color label runs were evaluated at separate times on the same printing press. Two different press operators produced different sizes and colors of labels during the runs. A brief description of the label printing in this project are as follows:

1. green labels, approximately 3.25 x 13 inches, printed with green ink (yellow premixed with blue) on non-glossy white stock for a total run of approximately 55,000 labels; and

2. purple labels, approximately 0.75 x 1.75 inches, printed with purple ink on glossy white stock for a total run of approximately 250,000 labels.

In each case the total weight of materials added, equation 1, and the weight of materials remaining at the end of the run was 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.

During the printing of the green labels, an ink pump was used to increase the size of the ink reservoir. Ink was continually recirculated between the ink pump and the ink pan. The weight of the ink pump and ink contained in it was determined at the beginning before any labels were printed, B in equation 1. During the course of that run water was added to the ink to adjust the color and viscosity on nine occasions totaling 847.2 grams, C in equation 1. One spill, F in equation 1, occurred during this run. The ink pan and gaskets adjacent to the roller were weighed before and after the run to measure the amount of ink retained on them after they were scraped, E in equation 1. During the printing of the purple labels nothing was added, and there was no loss due to spillage.

The total weight of ink used during the printing of these two labels is shown in Table 7. For the two water-based inks the total amount used was calculated according to equation 1. To estimate the amount of ink evaporated, the percent loss as determined by laboratory evaporation was used according to equation 2. The laboratory evaporation results are shown in Table 8. The amount of solids retained on the labels was calculated from the percent solids ascertained in the laboratory as applied in equation 3.

To estimate emissions that would have resulted from using alcohol-based inks, it was assumed that the same amount of solids would have been used for printing the labels as was used for printing with the water-based inks. Then the total amount of ink that would have been used and the weight evaporated was calculated by using the percent loss factor determined in the laboratory. Since a lower percentage of alcohol-based ink was lost to evaporation, more solids per gram of inks would be applied to the labels than with the water-based ink. Thus, less total alcohol-ink would be used and less total weight of components would be lost via evaporation. According to the operators at MPI Label Systems, about the same total amount of ink is required for a job using either type of ink. Therefore, this analysis of emissions is conservative for the alcohol-based ink. It should be noted that laboratory evaporation loss results presented in Table 7 agree favorably with the total volatiles data given in the material safety data sheets, as shown in Table 3.

TABLE 7. INK USED AND ESTIMATED EMISSIONS

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

TABLE 8. WEIGHT LOSS DATA FROM LABORATORY EVAPORATION AT 70°C

Material	Initial weight grams	Dry weight grams	Weight loss grams	Percent Loss	Standard deviation
Black water-based ink	09.82	04.24	05.58	56.8	0.42
	12.7	05.58	07.10	56.0	
	14.0	06.08	07.94	56.6	
Green water-based ink	10.7	04.47	06.20	58.1	0.21
	13.4	05.61	07.75	58.0	
	12.1	05.04	07.07	58.4	
Purple water-based ink	10.4	03.98	06.41	61.7	0.20
	14.0	05.31	08.70	62.1	
	12.3	04.68	07.60	61.9	
Black alcohol-based ink	11.8	06.21	05.59	47.4	0.60
	16.2	08.33	07.88	48.6	
	18.1	09.44	08.67	47.9	
Detergent cleaner	10.5	0.236	02.25	97.8	0.03
	13.6	0.301	02.21	97.8	
	13.6	0.297	02.19	97.8	

The next step is to estimate the weight of air and water emissions of each specific component of the inks studied. These estimates are presented in Tables 9 - 12, and were made using the percent composition data from Table 3. For the water-based inks it was assumed that all of the alcohol, ammonia and amine evaporated and that the remainder of the loss was water.

Concentrations of each volatilized constituent in the plant air were calculated based on the volume of air in the shop area and the air exchange rate. These concentrations are levels expected during continual operation of the press assuming all six print stations are being used to apply ink. Also it is assumed that exposure to emissions from the cleaners was negligible and that they were entirely discharged to the sewer. Under typical plant conditions and exposures to employees, peak concentrations may exceed the levels presented.

TABLE 9. ESTIMATED AIR AND WATER EMISSIONS AT MPI LABEL SYSTEMS FOR TEST RUN WITH GREEN LABELS AND WATER-BASED INK AND CLEANER

Components of ink and cleaner	Amount of air emissions, grams	Concentration in the air, ug/l	% of total air emissions	Amount in wastewater, grams	Concentration in wastewater, ug/l	Total % in wastewater
Isopropyl alcohol	72.9	06.0	8.0	1.2	317	1.7
Ammonia	14.6	01.2	2.0	0.2	52.8	0.30
Dimethyl ethanolamine	14.6	01.2	2.0	0.2	52.8	0.30
Water	747	62	88	16	4230	23
Acrylic resin	-	-	-	4.9	1290	7.1
Azo pigment	-	-	-	2.0	528	2.9
Water in cleaner	-	-	-	44	11700	64
Total	849.1	-	100	68.4	-	100

Air emissions for printing with both types of inks were assumed to be entirely from the inks. The fate of the cleaner components was assumed to be in the wastewater. For the two scenarios with green labels, about 50% more air emissions resulted from the water-based inks. However, most of these emissions, 88%, were the water component. By contrast, about 80% of the emissions from the alcohol-based inks and cleaners were calculated to be various alcohols. Much lower concentrations of the non-water constituents were estimated to be present than with the alcohol-based green ink.

A pattern similar to the air emissions was found with the purple labels. Of some concern with the water-based inks are the ammonia and dimethyl ethanolamine components that are released. With the alcohol-based inks four alcohols plus ethyl acetate and VM&P naphtha are released to the shop air.

Overall, more grams of inks and cleaner components were estimated to be released to the shop air than were disposed of in the wastewater. This is because about 50% of the inks used is evaporated and almost all of the liquid ink remaining in the reservoir at the end of the press run is returned to its original container for reuse.

TABLE 10. ESTIMATED AIR AND WATER EMISSIONS AT MPI LABEL SYSTEMS FOR TEST RUN WITH GREEN LABELS AND ALCOHOL-BASED INK AND CLEANER

Components of ink and cleaner	Amount of air emissions, grams	Concentration in the air, ug/l	% of total air emissions	Amount in wastewater, grams	Concentration in wastewater, ug/l	Total % in wastewater
Methyl alcohol	49.2	4.1	09	1.1	290.6	1.6
Isopropyl alcohol	111	9.2	20	2.6	686.9	3.8
n-propyl alcohol	68.0	5.6	12	1.6	422.7	2.3
Ethyl alcohol	224	18	40	5.3	1400	7.7
Ethyl acetate	44.0	3.6	08	1.0	264.2	1.5
VM&P naphtha	69.1	5.7	12	1.6	422.7	2.3
Resins	-	-	-	5.7	1510	8.3
Pigment	-	-	-	5.7	1510	8.3
Toluene	-	-	-	24	6370	35
Acetone	-	-	-	8.9	2350	13
Isopropyl alcohol	-	-	-	8.9	2350	13
Diacetone alcohol	-	-	-	2.4	634.1	3.5
Total	565.3	-	100	68.9	-	100

Liquid wastes were generated only during cleanup at the end of each press run. These wastes were minimal and consisted of ink left in the pan and on the rollers, gaskets and plates at the end of the run after scraping, plus detergent cleaner. For the green run, 116.6 grams of ink remained in the pan. A total of 44.3 grams (approximately 44 ml) of cleaner was used. All of this was disposed of as wastewater for a total of 160.9 grams. During the cleanup of the purple labels only 56.4 grams of liquid waste was produced. All of this excess ink was returned to the ink container for use on subsequent runs. There was a more experienced operator for this run which resulted in less cleanup being required and less wastage. No liquid wastes were generated except for a negligible amount on a few cleanup rags. During these two runs most of the ink retained on the fabric rags resulted from a spill that occurred during printing of the green labels. A total of 24.6 grams of inks was cleaned up as a result. These rags were sent to an industrial laundry for cleaning and reuse. Thus, this spilled ink also resulted in a liquid waste.

TABLE 11. ESTIMATED AIR AND WATER EMISSIONS AT MPI LABEL SYSTEMS FOR TEST RUN WITH PURPLE LABELS AND WATER-BASED INK AND CLEANER

Components of ink and cleaner	Amount of air emissions, grams	Concentration in the air, ug/l	% of total air emissions	Amount in wastewater, grams	Concentration in wastewater, ug/l	Total % in wastewater
Isopropyl alcohol	20	05.3	8.0	0.6	158	1.1
Ammonia	04.0	01.1	2.0	0.1	26.6	0.20
Dimethyl ethanolamine	04.0	01.1	2.0	0.1	26.6	0.20
Water	219	58	88	7.9	2090	14
Acrylic resin	-	-	-	2.4	634	4.3
Azo pigment	-	-	-	1.0	264	1.8
Water in cleaner	-	-	-	44	11700	79
Total	248	-	100	56.1	-	100

TABLE 12. ESTIMATED AIR AND WATER EMISSIONS AT MPI LABEL SYSTEMS FOR TEST RUN WITH PURPLE LABELS AND ALCOHOL-BASED INK AND CLEANER

Components of ink and cleaner	Amount of air emissions, grams	Concentration in the air, ug/l	% of total air emissions	Amount in wastewater, grams	Concentration in wastewater, ug/l	Total % in wastewater
Methyl alcohol	12.3	3.3	8.7	0.6	158.6	1.1
Isopropyl alcohol	27.7	7.3	20	1.3	343.5	2.3
n-propyl alcohol	17.0	4.5	12	0.8	211.4	1.4
Ethyl alcohol	55.9	15	40	2.6	686.9	4.6
Ethyl acetate	11.0	2.9	7.8	0.5	132.1	0.9
VM&P naphtha	17.2	4.6	12	0.8	211.4	1.4
Resins	-	-	-	2.8	713.3	4.9
Pigment	-	-	-	2.8	713.3	4.9
Toluene	-	-	-	24	6370	43
Acetone	-	-	-	8.9	2350	16
Isopropyl alcohol	-	-	-	8.9	2350	16
Diacetone alcohol	-	-	-	2.4	634.1	4.3
Total	141	-	100	56.4	-	100

DEGREE-OF-HAZARD

The Degree-of-Hazard analysis was conducted on the components generated in the liquid wastes and the air emissions from the alcohol-based inks and cleaners versus the water-based inks and cleaners. For the liquid wastes the toxicity values were based on oral toxicity. For the air emissions the toxicity values were based on inhalation toxicity when such data were available. This enhancement of the program demonstrates the flexibility for the degree of hazard system to accommodate the physical form of the waste stream or the exposure route.

The equivalent toxic concentration, C_{eq} of equation 5, for the liquid wastes and air emissions for the green and purple ink runs were calculated. The results of these calculations for liquid wastes and air emissions for the alcohol-based ink and cleaner are presented in Tables 13 - 16. Tables 13 and 14 present the data on liquid wastes for the green and purple alcohol-based inks and cleaners. The equivalent toxic concentration for the green ink liquid alcohol waste was a value of 3.084 compared to the value for the purple ink liquid alcohol waste which was 3.323. The calculated values for the water-based liquid wastes, as shown in Tables 17 and 18, were about one tenth of the level for the alcohol-based liquid wastes.

TABLE 13. DEGREE-OF-HAZARD ANALYSIS FOR MPI LABEL SYSTEMS GREEN ALCOHOL-BASED INK AND CLEANER, LIQUID WASTE

Component name	Percent concentration	Component equivalent toxic concentration
Toluene	35	2.100
n-propyl alcohol	2.3	0.369
VM&P naphtha	2.3	0.352
Diacetone alcohol	3.5	0.263
Isopropanol	17	Innocuous
Acetone	13	Innocuous
Ethyl acetate	1.5	Innocuous
Ethanol	7.7	Innocuous
Methanol	1.6	Innocuous
Acrylic resin	8.3	Innocuous
Azo pigments	8.3	Unknown
Total		3.084

TABLE 14. DEGREE-OF-HAZARD ANALYSIS FOR MPI LABEL SYSTEMS PURPLE ALCOHOL-BASED INK AND CLEANER, LIQUID WASTE

Component name	Percent concentration	Component equivalent toxic concentration
Toluene	43	2.562
n-propyl alcohol	1.4	0.225
VM&P naphtha	1.4	0.214
Diacetone alcohol	4.3	0.323
Isopropanol	18	Innocuous
Acetone	16	Innocuous
Ethyl acetate	0.09	Innocuous
Ethanol	4.6	Innocuous
Methanol	1.1	Innocuous
Acrylic resin	4.9	Innocuous
Azo pigments	4.9	Unknown
Total		3.323

TABLE 15. DEGREE-OF-HAZARD ANALYSIS FOR MPI LABEL SYSTEMS GREEN ALCOHOL-BASED INK AND CLEANER, AIR EMISSIONS

Component name	Percent concentration	Component equivalent toxic concentration
n-propyl alcohol	12	1.925
VM&P naphtha	12	1.837
Ethyl acetate	08	0.060
Ethanol	40	0.024
Isopropanol	20	0.015
Methanol	09	0.002
Total		3.863

TABLE 16. DEGREE-OF-HAZARD ANALYSIS FOR MPI LABEL SYSTEMS PURPLE ALCOHOL-BASED INK AND CLEANER, AIR EMISSIONS

Component name	Percent concentration	Component equivalent toxic concentration
n-propyl alcohol	12.0	1.925
VM&P naphtha	12.2	1.867
Ethyl acetate	07.8	0.058
Ethanol	39.6	0.024
Isopropanol	19.6	0.015
Methanol	08.7	0.002
Total		3.891

TABLE 17. DEGREE-OF-HAZARD ANALYSIS FOR MPI LABEL SYSTEMS GREEN WATER-BASED INK AND CLEANER, LIQUID WASTE

Component name	Percent concentration	Component equivalent toxic concentration
Ammonia	0.30	0.257
Dimethylethanolamine	0.30	0.450
Water	87.5	Innocuous
Isopropanol	1.70	Innocuous
Acrylic resin	7.10	Innocuous
Azo pigments	2.90	Unknown
Total		0.302

TABLE 18. DEGREE-OF-HAZARD ANALYSIS FOR MPI LABEL SYSTEMS PURPLE WATER-BASED INK AND CLEANER, LIQUID WASTE

Component name	Percent concentration	Component equivalent toxic concentration
Ammonia	0.20	0.171
Dimethylethanolamine	0.20	0.030
Water	92.5	Innocuous
Isopropanol	1.10	Innocuous
Acrylic resin	4.30	Innocuous
Azo pigments	1.80	Unknown
Total		0.201

The equivalent toxic concentration for the air emissions for the green and purple alcohol-based inks and cleaners were 3.863 and 3.891, respectively. The equivalent toxic concentration for the air emissions for the green and purple water-based inks and water based cleaners were both 0.318 and shown in Tables 19 and 20.

TABLE 19. DEGREE-OF-HAZARD ANALYSIS FOR MPI LABEL SYSTEMS GREEN WATER-BASED INK AND CLEANER, AIR EMISSIONS

Component name	Percent concentration	Component equivalent toxic concentration
Ammonia	2.0	0.012
Dimethylethanolamine	2.0	0.300
Water	88	Innocuous
Isopropanol	8.0	0.006
Total		0.318

TABLE 21. SUMMARY OF EVALUATION OF ANNUAL COSTS AND SAVINGS

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
Total Annually	At least $16,500

A significant offsetting factor was MPI Label Systems' decision to install a unit to decolor its waste inks prior to discharge to the sewer. The capital cost of this unit was approximately $18,000 and the colored absorbent is acceptable at the local municipal landfill. Since this treatment unit was not required by the local publicly owned treatment works (POTW) as part of the change to water-based inks, its purchase and operating costs are not included in this analysis. There are areas which require ink waste to be treated before discharge to the sewer. For those areas where pretreatment is a requirement, the savings in the first year should be offset.

SECTION 5

QUALITY ASSURANCE

The quality assurance/quality control (QA/QC) project plan submitted for this project was written to validate the quantitative comparison of the volume and toxicity of any waste generated during printing and released as gaseous, liquid and solid wastes, before and after switching to water-based inks and a detergent cleaner, and the economic impact resulting from modification of a traditional printing technology.

The on-site mass measurements were taken on an electronic balance (capacity 12 kgs $\pm$ 0.01 g) which was transported to the printing site. After transportation the balance was calibrated using its internal calibration function, and checking the calibration using Class S weights.

The laboratory samples were analyzed in triplicate with results presented in Section 4. These results show that none of the individual analyses were outliers. The standard deviation for the triplicate analyses ranged from 0.03 - 0.60.

The data collected initially for this project had to be dismissed because MPI Label Systems set up for the print run the night before. This did not allow the initial mass measurements of the inks to be taken. Great efforts were made, during the second attempt, to ensure that the quality data objectives for this project were not compromised. The original data quality objectives stated in the QA/QC project plan were met on this project.

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