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WASTE REDUCTION EVALUATION OF SOY-BASED INK AT A SHEET-FED OFFSET PRINTER

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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 waste, and Superfund-related activities. This publication is one of the products of that research and provides a vital communications link between the researcher and the use community.

This document presents the results of an experiment conducted to quantify and compare wastes generated from the use of soy-based and petroleum-based inks. It also examines the economics of using both petroleum-based and soy-based inks.

E. Timothy Oppelt, Director

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ABSTRACT

This Waste Reduction Innovative Technology Evaluation (WRITE) project quantifies and compares wastes generated from the use of soy-based and petroleum-based inks in sheet-fed offset printing. Data were collected in a full-scale print run on a Miller TP104 Plus 6-color press in July 1992 at the Office of Printing Services, University of Illinois, a medium-size in-plant printer in Champaign, IL. Four petroleum-based inks and four soy-based inks were studied in a 4400 sheet work-and-turn print job. The amounts of each ink used, each cleaner used, wastes on cleaning rags, and wastes in the wash-up trays were measured for each print run. Each ink and each cleaner was analyzed for total solids and volatiles content. Quantities of air emissions, liquid wastes, solid wastes and costs were estimated and compared for the two print runs.

Ink usage was about 17% greater for the petroleum-based ink run. Cleaner use was about 4% less for the soy ink run. The two inks required about the same effort to clean from the presses. There was over 80% less volatile components in the soy-based inks (average of about 0.8% compared to about 4.6% for the petroleum-based inks). For each ink, over 99% of the air emissions generated during the printing runs studied originated from the cleaners. In contrast, over 90% of the liquid wastes on rags and in the washer trays originated from the inks. Make-ready differences between the two runs and variability in manual cleaning make comparisons between use of the two inks difficult in cleaner usage. There were no observed reasons why the amount of liquid wastes generated from cleaning these inks would differ. Similarly, solid waste generation would generally be expected to be the same. The print run using soy-based inks resulted in slightly less costs in ink and cleaner usage.

Operating efficiency (such as preventing spills and using only the amount of cleaner needed for the test) can have a greater impact on waste generation and costs than the type of ink used.

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SECTION 1

INTRODUCTION AND BACKGROUND

This project, part of the Illinois-EPA WRITE Program, focuses on one of five technologies being evaluated by the Hazardous Waste Research and Information Center (HWRIC) for potential contribution toward waste reduction or pollution prevention. This project is a joint effort of the University of Illinois' Office of Printing Services (OPS), the Illinois Department of Energy and Natural Resources through HWRIC, and the US EPA's Risk Reduction Engineering Laboratory. The goal of the study is to evaluate the waste reduction and economic effects of using soy-based inks in place of the petroleum-based inks traditionally used in sheet-fed offset printing.

STATEMENT OF THE PROBLEM

Since the late 1950's, print shops have relied on petroleum-based inks and, for a longer time, solvent-based cleaners in their operations. Soy-based news inks, where soy oil completely replaced the nondrying petroleum oils as the ink vehicle, were first produced in 1985 by the American Newspaper Publishers Association for printing newspapers. The impetus for this development initially came from the oil shortages of the 1970's that threatened the supply of petroleum-based chemicals, including inks. However, increased emphasis on improving worker safety and reducing emissions to land, air and water also motivated the lithographic printing industry to seek "cleaner" technologies, without sacrificing print quality.

Alternative ink formulations, producing lower volatile organic compounds (VOCs), for the lithographic and letterpress printing industry have been developed with soy oil. Offset inks are composed of four main components. These are termed pigments, varnish, aliphatic petroleum distillates and additives (wax, driers and antioxidants). Pigments typically comprise 15 to 20% of the volume. Additives comprise another 3 to 10% of the volume. In petroleum inks, petroleum distillates can comprise up to 20% of the volume and the varnish comprises the remaining volume of 45 to 60%. The varnish can contain various oils such as linseed oil and resins. The composition of offset inks differs in that the aliphatic petroleum distillate composition is reduced to about 10% of the volume and soy oil is used in the varnish. Ink manufacturers have not been able to satisfactorily replace all of the petroleum oils with soy oil or other vegetable oils in offset inks.

Soy inks were first produced for the lithographic and letterpress newsprint industries, and by 1989 they were being marketed to the entire offset printing industry. Today, sheet-fed soy inks are defined as those inks that have a minimum of 20% soy oil. These inks are then allowed to use the Soy Seal Trademark issued by the American Soybean Association. The soy oil replaces all or some of the nondrying petroleum oils in the ink vehicle. Soy ink is being used by several types of printers throughout the US and it reportedly has a variety of advantages over the traditional petroleum-based inks. Soy ink is advertised as being partially biodegradable in landfills, it releases less volatile organic chemical emissions than petroleum-based inks, is a renewable resource, and is more conducive to printing press cleanup than petroleum-based inks. Soy-based ink is thought to be advantageous for the environment and agriculture because it can be domestically produced and alleviates some health and safety concerns through reduced VOC emissions. In addition, vegetable oil inks are said to be economical because they reportedly spread further and allow for quicker press start-up (Scarlett, 1992). If that is the case, less time, paper and ink would be used in setting up printing jobs and less ink would be required to complete the job compared to printing with petroleum-based inks.

Ease of cleaning inks from printing presses is an important factor for operator acceptance, productivity, cost savings, and environmental impact. Some cleaners are highly volatile and contain toxic chemicals. If soy inks can be cleaned more easily or with less toxic chemicals then the amount of liquid wastes and air emissions generated will be reduced. In this study, the same set of cleaners were used for each type of ink. Ease of cleaning and the amount of cleaners used for the two types of inks were investigated.

OFFSET PRINTING PROCESS

The original printing system, now called "letterpress," consisted of assembling metal or wooden letters in a locking form, inking the surface of all the letters, then pressing a sheet of paper against the letters to pick up the ink. This was the system first used by Johann Gutenberg in 1440 and, with very few improvements, it persisted for over 500 years.

As printing technology developed, more efficient lithographic techniques replaced movable type. Lithography began with drawing a wax-based design on a stone. The non-design part of the stone is then wetted with an aqueous wetting solution which permits a suitable ink to transfer the design to a sheet of paper. In effect, the water repels the ink, and only the inked design is transferred. In the 1940's it was discovered that a metal plate can be made to function much like a lithographic stone. More recently various polymer plates have been developed. With a plate, the portion representing text or a design can be coated with the proper ink after the portion with no design has been wetted with a water solution to repel the ink. The flexible plate is wrapped around a metal cylinder and transfers/offsets its inked design to an intermediate blanket, and then to paper. When single sheets of paper are fed into such a press it is termed "sheet-fed offset". If a continuous length of paper (or web) is used, the press is called a "web offset." Many offset printing operations now set up each page via computer input.

Figure 1 is the schematic layout for a single color station typical of a sheet-fed offset press without the paper feed, drying mechanism, and finished product receptacle. A six-color press requires a similar assembly for each color, including ink pan, plate, a transfer mechanism, and many rollers. The offset printing press is complex, and calls for a large number of adjustable parameters including roller pressure, paper alignment, and ink film thickness (Brewer, 1971). For newspapers, magazines and other publications individual stories and advertisements are written, edited, and pasted into a single electronic page which is then either typeset and photographed or transferred directly to film in order to provide the plate required for offset printing.

In Illinois there are approximately 3800 printing facilities that operate offset presses. Of those facilities, 3550 operate sheet-fed offset presses, 160 operate both web and sheet-fed presses, and 250 facilities operate with only web offset presses. About 3200 of these facilities have one-color sheet-fed offset presses. In addition, 1725 of the 3200 have presses over 22" wide.

OFFICE OF PRINTING SERVICES

The operating partner in this project is the Office of Printing Services (OPS) at the University of Illinois in Champaign, Illinois. OPS is primarily an in-plant printer as opposed to a commercial printer, i.e., they print materials only for their parent organization, in this case, the University of Illinois. They are considered a medium size in-plant printer and gross $4.5 million annually. Typical OPS print jobs include posters, brochures and programs for campus activities and forthcoming events, and departmental materials.

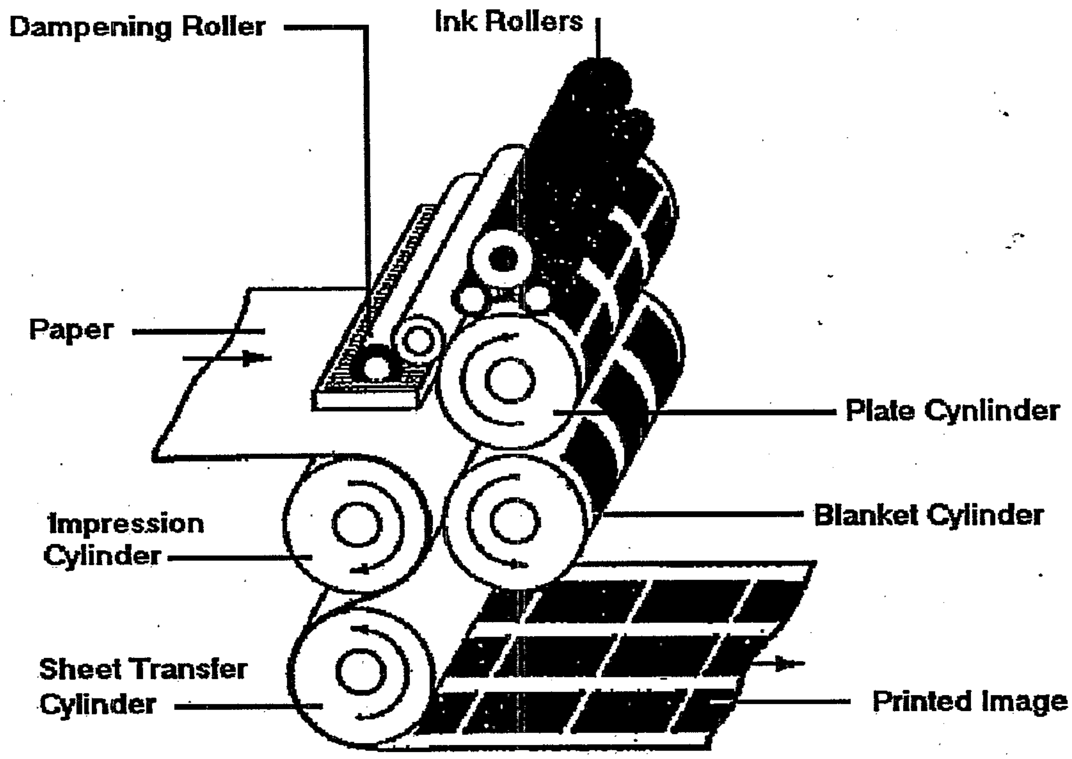

Figure 1. Inking and damping roller detail for a single color offset press

OPS's print shop occupies the top floor of a two-story university building that was built for OPS in 1964. Modifications have been added to suit the increasing needs of the printing operation. Currently, the operating press floor, including an administrative office and several rooms for photo preparation and editing, covers about 5,000 square feet. There are eight letterset and eight off-set presses of various ages and types in the shop. The Miller TP104 Plus sheet-fed offset press used for this study is capable of printing six colors on 23" X 47" sheets at a maximum rate of 10,000 sheets per hour.

In 1989 air monitoring was conducted at OPS by the University of Illinois' Division of Environmental Health and Safety. Air samples were tested for benzene, toluene, xylene, trimethylbenzene, Stoddard solvent, 1,1,1-trichloroethane, and ethanol. Although none of the OSHA permissible exposure limits (PEL) were exceeded or even approached for the eight-hour monitoring period, some recommendations were made to improve ventilation. Those recommendations, which are being implemented, were to 1) provide general air dilution for the offset press area with a minimum of 20 cubic feet per minute of fresh air make-up per person (ASHRAE 62-1981), and 2) maintain negative air pressure in the offset press area in relation to adjoining rooms to keep fumes from infiltrating other work areas.

The OPS staff agreed to enter into this cooperative project because of their commitment to employee safety and to active research participation as a University of Illinois organization, and because of their desire to be a model environmentally-aware print shop. The solvents used to clean the presses are also of concern to OPS, since they are also a significant source of air emissions (volatile organics). Marketers claim that soy ink requires less cleaner for press cleanup and that alternative cleaners of lower VOC content can be used for this cleanup compared to petroleum based inks. One bench top study, using letterhead paper, and another at Western Michigan University showed that soy oil releases from the paper pulp more easily, so paper recycling causes less damage to the pulp fibers when de-inking. This costs less and yields better quality recycled paper (Serafano 1991 and Harbin, no date). Improved quality of recycled paper helps to insure a steady market for the product.

During the 2 years prior to the study, OPS tried various types of soy inks and alternative cleaners. They found printing with the newer soy inks to be very satisfactory and now use them as much as possible. For some colors satisfactory soy inks are not yet available from their vendor. For those colors petroleum inks are used. After testing several alternative cleaners OPS has settled on using the same cleaners for both petroleum and soy inks. Press operators found the alternative cleaners they tested took longer to clean, did not remove the inks easily and some left a cloudy film which later had to be removed.

At OPS, as with most printers, work quality is given top priority. After a project is set up on a press and the chief operator considers it ready to run, one sample must be approved by the shop foreman and a second must be approved by the University customer. This latter step assures customer satisfaction. Because of this emphasis on quality, any proposed changes in the printing process to reduce waste, including plates, inks, cleaners, and paper, must be thoroughly examined before they are adopted.

INK INDUSTRY

According to a 1987 National Association of Printing Ink Manufacturers, Inc. (NAPIM) "Census of Manufacturers," U.S. ink manufacturers employed 11,100 persons in 504 ink manufacturing facilities; 1700 persons were employed in 50 ink manufacturing plants in Illinois alone. Of the 504 establishments, 208 or 41% manufacture lithographic and offset inks. These 208 offset ink manufacturing plants employ 5,800 persons. The total value of products shipped for offset inks in the

U.S. in 1987 was $987.3 million of which $128.7 million, or 13%, came from Illinois firms. For all printing ink manufacturing in the U.S. in 1987, the total value of shipped products was approximately $2.4 billion. The total amount of sheet-fed offset inks shipped in 1987 was 20 million pounds. The total cost of materials, services, and fuels, and electric energy used by ink manufacturing establishments was $1.4 billion per year (NAPIM, 1987).

Over one third of the nation's 9,000+ newspaper printers are now using either black or colored soy ink. Most ink manufacturers are now using soy oil as a pigment vehicle, and they are formulating soy inks for their sheet-fed, heat-set, and forms ink customers. According to the American Soybean Association, for ink manufacturers to obtain the rights to display the SoySeal™, their soybean oil-based ink must use soybean oil as its only vegetable oil ingredient. Also, the minimum soybean oil content required to use their seal ranges from 10 percent to 55 percent depending on whether it is a news, sheet-fed, forms, or heat-set ink (Cooke, 1991).

LIQUID CLEANING AGENTS FOR OFFSET PRESSES

Printing presses require meticulous cleaning. Most cleaners are formulated for cleaning specific parts of a press including rollers, blankets, and cylinders. Some printers have traditionally used organic solvent cleaners, in some cases even gasoline and kerosene, because offset inks have responded best to these cleaners and they were affordable. These products are considered hazardous (flammable) materials.

Alternative cleaning agents are now being formulated to use with vegetable-based ink products. These alternative cleaners generally contain less hazardous materials than traditional cleaners. Less toxic solvents have been substituted for traditional solvents, and in some cases aqueous cleaners have been substituted for solvent cleaners (USEPA, 1989; Ferris, 1992). For example, over the years benzene has been replaced by less toxic aliphatic solvents such as Stoddard solvent and naphthas.

Many halogenated compounds have also been replaced (USEPA, 1990). Extensive information is available on existing cleaning agents (Mazerall, 1987; Evanoff et al., 1988; Hayes, 1988).

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

In terms of the amounts of inks and cleaners used in the two print runs, comparisons were complicated because approximately 25% more pages were printed using petroleum inks. The extra pages resulted from excess moisture which caused wrinkling in the first batch of paper used. For this press, the same cleaners were used for both types of inks. Cleanup was more rigorous at the end of the run using soy inks. For this specific print job, approximately 17% more petroleum-based inks were used than soy-based inks to complete an identical image print run (after correcting for differences between the runs). Overall, the amount of cleaners used was about 4% less for the soy ink run after adjusting for differences in the length of the runs. In both cases, the inks were equally easy to clean from the presses. Typically the same amount of time, effort and amount of cleaners would be required for both inks.

Both types of inks had low contents of volatile components, with soy-based inks having significantly less than the petroleum-based inks. Based on laboratory drying measurements, soy-based inks averaged about 0.8% volatile components and petroleum-based inks averaged 4.6% volatile components. Thus, the soy inks release only about 17% of the mass of volatile chemicals upon drying. The roller and blanket cleaners used at OPS had greater than 97% volatile content. With both types of ink, over 90% of the liquid wastes originated from the inks and over 99% of volatile chemical emissions resulted from use of the cleaners (99.4% with the petroleum inks and 99.6% with the soy inks). Since most of the air emissions were from the cleaners, less than a 1% overall reduction in air emissions resulted from using the soy-based inks. The longer the print run the greater the reduction in volatiles from using soy inks.

The sources of liquid wastes that were generated were the cleanup rags and washup trays. It was determined that about 60 per cent more liquids were on the rags after cleaning the press after the petroleum ink run. In addition, almost 10 per cent more liquids were generated in the washup trays after the petroleum ink run. However, because of various differences in the two runs and imprecise metering of cleaners, it is not possible to conclude that the petroleum inks generated more liquid wastes than the other soy inks.

Due to problems with excessive moisture content in the paper at the beginning of the petroleum ink run, 1,375 printed pages had to be discarded as solid waste. In contrast, at the beginning of the soy ink print run only 100 pages were wasted during make-ready. That is closer to the amount of solid waste that would typically be generated during setup on an automated press. Normally there would be no significant difference in paper wasted during make-ready because of ink type. It is important to properly store the paper to reduce solid waste. Automated plate and press alignment is also beneficial for reducing solid waste generated during make-ready. Because the soy inks generally spread further (by an average of about 17%), less used ink containers may be generated with these inks.

For this study, the most important cost comparison factors are the price of the raw materials and amounts used. At OPS there is no difference in the average cost of the two types of inks. Generally soy inks tend to cost about 10% more. For the relatively small print job studied (4,951 pages), it was estimated that the cost savings from printing with soy inks, since less were used, was about $1.20. Over the course of a year with multiple print jobs this cost savings would accumulate. However, this cost difference would be small compared to other costs that printers have to consider.

Thus, a 10% cost difference in the price of inks is not a major factor to printers. The two print runs only differed by 5 cents in the cost of material to clean the press. The soy-based ink cost $5.67 to clean while an equivalent petroleum-based ink cost $5.71.

The greatest potential for reducing wastes in offset printing would be to use less volatile cleaners and modify the presses so that less inks and cleaners would have to be wasted. Currently, the operators at OPS have not been able to find an acceptable aqueous or very low volatile cleaner. For the type of press studied, an automated blanket wash system could be installed to reduce the amount of cleaner used. The utilization of automated blanket wash systems could reduce the amount of cleaner used by up to 33%, thus reducing air emissions from those cleaners by that percentage. These systems are costly and may be beyond the means of most printers. The payback period for such a system at OPS was estimated to be about 3 years which may be longer than most printers are willing to accept.

Overall, soy inks have some environmental and other advantages for sheet-fed offset printers. The main environmental advantage with use of soy inks is that they release less than 20% of the mass of volatile organic chemicals compared to petroleum inks. The soy inks also spread about 15% further which offsets the small difference in cost that currently exists. Reportedly, recycling of soy ink printed paper also has some advantages. All other factors such as make-ready time, appearance of printed product and clean up effort were essentially equivalent between the two types of inks in this study.

SECTION 3

MATERIALS AND METHODS

Data for this study were collected during a full-scale print run on a Miller TP104 Plus six-color press on July 17, 1992 at the Office of Printing Services (OPS). The print job was a 4400 sheet, six-color, work-and-turn, i.e., the printed image was identical for both sides of the sheet (this job was selected to insure that operating conditions during the two runs were as similar as possible). A three-panel folder was printed on one side with soy inks, and the other with petroleum-based inks. The press was cleaned and set up between the use of the two types of inks to allow measurements of the amount of materials used and waste generated. It should be noted that during a regular work-and-turn job if the inks were not changed the press would not have been cleaned between the runs. Only four of the six colors used were included in this study because two colors were a mixture of petroleum inks; soy inks were not available for those colors. The operating conditions of the press were the same for each run. All inks used in the study were manufactured by Handschy, Inc. A review of Material Safety Data Sheets from three ink suppliers (Alden & Ott Printing Inks Company, Arlington Heights, IL; Handschy Industries, Inc., Bellwood, IL; and Sinclair and Valentine, L.P., St. Paul, Mn) indicate that both types of inks contain high boiling point petroleum distillates but that soy inks tend to have a slightly lower boiling range (450 - 600 °F compared to 450 - 630 °F). For one of the companies, their blue colored petroleum ink contained manganese tallate while that chemical was not listed for their similar blue soy ink. A copper compound, at less than 5% by weight, was listed as an ingredient of another company's soy ink. The flash point for all inks used in this study is >200 °F.

The scope of the waste reduction evaluation attempted in this study was to compare the amount of air emissions, liquid wastes, and solid wastes generated during printing and cleaning with petroleum versus soy inks. Air emissions result from several activities beginning from when the ink containers are opened and ink is applied to the rollers, to make-ready and printing from the inks and use of cleaners, to final cleanup, and to storage of wastes on-site prior to disposal. Liquid wastes primarily are generated during cleanup. Inks and various cleaners are retained on the rags or wipers that are used to clean the presses. Also, there are wash up trays under the rollers that collect liquids during printing and cleaning. A difficulty in quantifying these liquid wastes and releases to the room air is that evaporation (loss from the liquids) occurs continually during the use of the inks and the highly volatile cleaners and even after clean up during storage of the liquid wastes. Ultimately the majority of the volatile portion of these wastes evaporates. Many print shops dispose of their liquid wastes from washup trays by sending them to a cement kiln or boiler. Liquids on discarded rags are either laundered (usually offsite) or are sent to a landfill. If the rags are laundered some volatile components are likely to be released while others along with the dried solids will be discharged to the local sewer. Solid wastes generated mainly include discarded paper, most of which is usually generated during make-ready, and rags. Other solid wastes generated in relatively small amounts include empty ink and cleaner containers. During this test no empty containers were generated. As is explained below, there were enough differences in make-ready for these two print runs that a fair comparison of the amount of scrap paper generated could not be made. OPS operators reported that there is no obvious difference in the amount of waste paper generated when using these two types of inks.

MATERIALS USE MEASUREMENTS

Because of the complexity of directly measuring wastes generated during printing and the changing composition of those wastes, the approach taken to estimating waste quantities was to first determine the amount of raw materials (primarily inks and cleaners) used. Ink use was measured by weighing the separate ink containers before and after the print runs. The ink remaining in the trays was transferred back to the ink containers before the latter measurement was taken. Measurements were taken on a Sartorius electronic balance (capacity: 12 kgs., ± 0.1 gm) at the printing site. After transport from the Hazardous Materials Laboratory to OPS, the scale was calibrated using the internal calibration function and checked with Class S weights.

Roller and blanket cleaners were used to clean the press each time it was stopped during make-ready, and at the end of each print run. Table 1 describes the chemical characteristics, as stated on the available Material Safety Data Sheets, of the cleaners used for the project. The same cleaners were used for both types of ink. The roller cleaners RBP #1 and #2 were manufactured by RBP Chemical Corporation (Milwaukee, WI), and the roller cleaner Mix is made at the Office of Printing Services. Each of these cleaners is used for a different purpose. RBP#1 is used first to remove inks from the rollers. This is followed by RBP#2 which is formulated to remove any remaining oils. The MIX cleaner is used at the end of each day to remove excess gum that may have built up on the rollers. It is not normally used after each printing run but was in this study for comparison purposes.

The blanket cleaner V-120 was manufactured by Varn Products Co., Inc. (Addison, IL), and Clean Quick was made by Volatile Stores at the University of Illinois (Champaign, IL). V-120 is used to clean the printing plates and usually the blanket. Clean Quick is used sparingly for deep cleaning and faster drying. In the past Clean Quick was the main plate and blanket cleaner used at OPS.

TABLE 1. SELECTED CHEMICAL CHARACTERISTICS OF THE CLEANERS USED DURING MAKE-READY AND FOR FINAL PRESS CLEANING

Cleaner	Listed Ingredients (Percentage)		Boiling Range °F	Flammability Flash Point °F
RBP #1	Light Aliphatic Solvent Naphtha	<75%	nd*	120
	Heavy Aromatic Solvent Naphtha	<20%		
	Diethanolamine	2%		
	Benzenesulfanic Acid Dodecyl Ester	<10%		
RBP #2	Stoddard Solvent	>99%	316-360	104
MIX	Water	49%	unknown	unknown
	Isopropyl Alcohol	49%		
	Lactic Acid	2%		
V-120	Petroleum Naphtha	<45%	320	106
	Petroleum Naphtha	<50%		
	Dipropylene Glycol Methyl Ether	<10%		
Clean Quick	Ethyl Alcohol	40%	unknown	unknown
	Toluene	60%		

* nd = no data were supplied by the manufacturer

The amount of each cleaner used was measured by weighing the cleaner in its container before the print run began and again after completion of the cleaning process at the end of the print run. The amount of each roller cleaner used at each unit of the press was recorded separately, while the quantity of each blanket cleaner was recorded for the four units combined. Measurements were taken on a Sartorius electronic balance (capacity: 12 kgs., ± 0.1 gm) located at the printing site.

ESTIMATING INK AND CLEANER AIR EMISSIONS

It was not feasible to directly measure air emissions because of the many point sources from the press, the difficulty of enclosing the entire printer, and the many other sources of volatile organics to room air in OPSs shop. Instead, a worst case assumption was made that all the volatile components of the inks and cleaners used evaporated in the shop. Emissions from the inks and cleaners were estimated by determining percent solids of the inks in laboratory tests and subtracting that amount from the total amount of each ink used.

The volatile proportion of each ink and cleaner was determined under controlled laboratory conditions simulating conditions on the press using a modified standard method. The method used to determine the percent solids and volatiles in each ink and cleaner was a modification of test method number ASTM D 2369, the Standard Test Method for Volatile Content of Coatings (ASTM 1991). A Denver Company Instrument IR-100 Moisture Analyzer was used to dry the samples. This instrument allowed the drying temperature to be adjusted to 70 °C, which more closely simulates drying conditions during the print run than the 110 °C called for in the standard method. Samples of each ink and each cleaner used during the print run were collected in glass vials with teflon-lined screw caps and delivered to HWRIC's Hazardous Materials Laboratory (HML) for laboratory analysis of solids and volatile content. Cleaners were handled using a disposable pipette to transfer a 1 gram sample of each cleaner to a quartz pad for drying. The ink samples, due to their high viscosity and tendency to form a 'skin' on the surface, were transferred with a clean spatula; care was taken to break through the upper, dry layer to access undried ink. The ink samples were then spread onto a previously tared clean microscope slide to form a thin layer. This resulted in a 0.1 - 0.3 gram sample. The microscope slide was then inserted into the Moisture Analyzer for drying and weight loss determinations.

The endpoint criteria was set for a <0.01% change in weight over a 3 minute period for the cleaners and <0.01% change over a 10 minute period for the inks. The instrument was activated and the analysis carried out automatically. Three to four subsamples of each ink and each cleaner were dried, and the mean was reported with the relative standard deviation. Analysis time was approximately 60 minutes for the inks and 10 minutes for the cleaners.

Laboratory data were analyzed using SAS (Statistical Analysis System) software. An Analysis Of Variance (ANOVA) test for data with unequal samples sizes was used to test for differences between the solids component of the soy inks and the petroleum-based inks.

ESTIMATING LIQUID WASTES FROM THE INKS AND CLEANERS

The mass of liquid wastes was measured directly during the print runs at the OPS facility. The sources of liquid wastes measured were the cleaning rags and washup trays. These were considered to be liquid wastes since the waste inks and cleaners were in liquid form at the end of the printing runs which is the point when they became wastes. Volatile components of these liquids are continually evaporating. Some of the inks and cleaners on the rags dry out over time. The maximum amount of liquid wastes generated was the amount measured on the rags and in the washup trays immediately at the end of cleanup. These amounts were used for comparison in this study. Due to evaporative losses, this quantity is not necessarily the amount of liquids that will eventually be sent off-site for disposal. It should also be noted that not all printers will manage these as liquid wastes. In some cases, these wastes are sent to a landfill. In other cases soiled rags are laundered.

The amount of waste on the rags was measured by first determining the weight of the dry rags before the printing process began. Prior to operation of the press the number and weight of the rags used to clean each unit of the press were recorded. After cleaning the press, the wet rags were re-weighed immediately to determine total liquid waste (ink and cleaners) in the rags. At the completion of each print run, the mass of waste (cleaners and ink) that remained in the wash-up trays at each press unit was determined.

Since these wastes are a mixture of leftover inks and cleaners, an effort was made to determine the proportion of the wastes from the cleaners and the remaining portion from the inks. The major unknown is the amount of inks applied to the printed paper. It is not possible to determine this gravimetrically because the weight of the paper overwhelms the relatively small amount of ink applied. Also, the paper constantly absorbs moisture from room air and inks continue to dry for hours after printing. Thus, the weight of the printed paper is not constant. The approach used was to assume that all the solids in the cleaners used ended up on the soiled rags. By subtracting this amount from the total amount of solids on the dried rags the amount of ink solids on the rags was determined. From that amount the total amount of liquid waste on the rags from the inks was determined from the proportion of volatile components in inks. Once the amount of liquid on the rags from waste inks was known the remaining liquid was assumed to be from the cleaners.

SECTION 4

RESULTS AND DISCUSSION

In this section, the results of the in-plant measurements of materials used and wastes produced are presented first. Next, the laboratory results of the solid and volatile components of the inks and cleaners are presented. This is followed by discussions of the amount of air emissions and liquid wastes calculated for the two print runs. Finally, a cost comparison of using the two inks is given.

There was a major difference in the two print runs that affected the difference in ink and cleaner usage and waste paper generated. Make-ready for the petroleum-based ink run was more involved than with the soy-based run. At the beginning of the petroleum-based ink run the paper curled from high humidity and new stock had to be obtained. Plates required registering and adjustments were made to assure proper ink color saturation during make-ready for the first run. The excess pages printed during make-ready had to be discarded. In each run 4,951 sheets of acceptable product were printed. During make-ready, for the petroleum ink run an additional 1,375 sheets were printed, while with the soy ink run only 100 make-ready sheets were printed. Thus, about 25% more pages were printed using petroleum inks. This problem accounts for some of the increased usage of petroleum ink and makes some comparisons between the two runs problematic. It is important to note that this extended make-ready was a problem with the paper that would have occurred if soy inks would have been used first. An attempt was made, based on differences in the amount of paper used during the two make-ready operations, to adjust the estimated materials use and waste generation. Both unadjusted and adjusted results are presented.

IN-PLANT MEASUREMENTS OF MATERIALS USE

The petroleum-based ink run required larger quantities of all four colors of ink than the soy-based ink print run (Table 2). In total, 562.1 grams of petroleum inks were used compared to 382.9 grams of soy inks. The increased use of petroleum inks ranged from 26% for red up to 60% for yellow. About 25% more petroleum ink usage would be expected because of differences in the amount of paper printed during make-ready. For each color, petroleum ink usage was more than 25% greater which indicates that less soy inks were required for an equivalent print job even after compensating for differences in the number of pages printed. On average, without adjusting for make-ready differences, almost 47% more petroleum inks were used.

TABLE 2. QUANTITY OF EACH INK USED DURING THE PRINT JOB

Ink Color	Ink Type	Ink Used(g)	Ink Used(g)/100 sheets
Black	Petroleum	241.8	3.8
	Soy	162.7	3.2
Blue	Petroleum	124.8	2.0
	Soy	79.5	1.6
Red	Petroleum	109.7	1.7
	Soy	87.1	1.7
Yellow	Petroleum	85.8	1.4
	Soy	53.6	1.1

The amount of each color of ink used per 100 sheets of paper printed is also shown in Table 2. On this basis about the same amount of each type of red ink was used. For the other colors, 18.8% more black, 25% more blue and 27% more yellow petroleum ink was used. In total, 17% more petroleum inks were used when compared on a per page printed basis (8.89g/100 sheets versus 7.58g/100 sheets for the soy inks).

An important factor that influences the amount of waste generated per unit of production is the length of the print run. Some uses of ink (and resulting wastes generated) in the printing process at OPS are fairly consistent between print jobs. For instance, the amount of ink required to coat the rollers and plates for each revolution is relatively consistent, although it does vary somewhat with the viscosity of the ink. A certain amount of waste is expected for every print job, but a higher proportion of waste is produced per page printed on shorter print jobs, such as the one monitored here. With longer print jobs, a greater percentage of the ink is used to fill the ink trays and coat the various rollers compared with the amount applied to acceptable product (USEPA, 1990)

The amount of blanket cleaners used is shown in Table 3. Almost 46% more blanket cleaners were used during the petroleum ink run (3,455.4 grams compared to 2,368.0 grams). Some of this difference can be attributed to the longer make-ready required. Blanket cleaners were used during the extended make-ready with petroleum inks. It was not possible to directly measure how much additional cleaners were used for that purpose during the printing run and that amount would not be directly proportional to the amount of paper printed. The amount of blanket cleaner used during make-ready was not recorded separately from that used during press cleaning at the end of the print run. Therefore, an equivalent comparison can not be made between the amount of blanket cleaners used for each print run.

TABLE 3. QUANTITY OF BLANKET CLEANERS USED DURING EACH PRINT RUN*

Ink Type	Cleaner	Initial Weight (g)	Final Weight (g)	Cleaner Used (g)
Petroleum	V120	3450.3	1681.6	1768.7
	Clean Quick	4921.4	3234.7	1686.7
Soy	V120	3471.9	2330.7	1141.2
	Clean Quick	4988.0	3761.2	1226.8

*Data are given for the whole print run, not for individual units (colors).

At the end of each printing run roller cleaners were used to clean up the presses. Differences in the amount of paper printed during make-ready did not affect the amount of roller cleaners used. However, the operators cleaned the press more thoroughly at the end of the soy ink run. The amounts of each roller cleaner used for each color and type of ink are shown in Table 4. Overall, about 30% more roller cleaners were used for the soy inks. The only instances in which more cleaners were used for the petroleum inks were with RBP#2 on the red and yellow stations.

TABLE 4. QUANTITY OF ROLLER CLEANERS USED AT EACH PRESS UNIT FOR THE PETROLEUM AND SOY INK PRINT RUNS

Ink Color	Ink Type	RBP #1 (g)	RBP #2 (g)	MIX (g)
Black	Petroleum	40.1	31.0	12.4
	Soy	78.8	43.5	27.9
Blue	Petroleum	44.8	34.5	33.8
	Soy	75.7	56.2	52.1
Red	Petroleum	29.5	75.8	19.5
	Soy	97.9	19.7	24.9
Yellow	Petroleum	35.1	96.6	61.5
	Soy	40.3	84.9	71.5

At the end of the petroleum ink run the ink in two of the stations was not changed. Also, since the same colors were going to be used in the next run, each press was not cleaned as thoroughly as they were at the end of the second run with soy inks. Since at the end of the soy ink run more time and effort was taken to clean each color station, it is not surprising that about 30% more roller cleaners were used. Both inks appeared to require approximately the same amount of cleaners and effort to remove from the presses. In typical practice, the amount of cleaner usage for the two inks would be expected to be about the same on average.

A summary of results of the in-plant measurements taken is given in Table 5. These results are without adjustments for differences between the two runs. The results from the four print stations are combined to show the cumulative differences in material use between the two runs. Also shown is the weight of solids on the clean-up rags after they were dried. Initially it was intended to weigh the amount of waste on the rags in the press room. Due to rapid evaporation it was not possible to determine a constant wet weight of the rags. As noted earlier, the rags were placed in plastic ziplock bags for transport to the Hazardous Materials

Laboratory for drying and weighing. The waste in rags and wash up trays at the end of the two runs cannot be compared on an equivalent basis due to differences in make-ready and the extra clean-up effort at the end of the second run.

TABLE 5. INKS AND CLEANERS USED AND WASTE PRODUCED FOR THE PETROLEUM AND SOY-BASED INK RUNS (g)

Parameter	Petroleum Print Run	Soy Print Run
Total Inks Used	562.1	382.9
Total Cleaners Used	3970.0	3041.4
Total Blanket Cleaners Used	3455.4	2368.0
Total Roller Cleaners Used	514.6	673.4
Dried Solids Waste in Rags	575.4	356.7
Liquid Waste in Wash-up Trays	663.8	604.5

LABORATORY RESULTS OF VOLATILE CONTENT

Based on results of the laboratory analysis of solids in the inks (Table 6) and cleaners (Table 7), all the inks had less than 6% volatile components and there were significantly less volatile components in the soy-based inks than in the petroleum-based inks ($p \leq 0.001$, $df = 1$, $f=80.3$). The petroleum inks had an average of about 4.6% volatile components compared to an average of about 0.8% for the soy inks. Thus, on average the soy inks only had about 17% of the amount of volatiles as the petroleum inks. The cleaners, except for RBP #1, contained > 97% volatile components (Table 8). The RBP #1 cleaner contained about 88% volatile components.

Based on these laboratory results and the amount of inks and cleaners used as shown in Table 5, the amount of solids and volatiles in the inks and cleaners was calculated. These results for each type of ink are

TABLE 6. RESULTS OF LABORATORY ANALYSIS TO DETERMINE SOLID AND VOLATILE COMPONENTS IN THE INKS USED

	Petroleum-Based Ink		Soy-Based Ink	
Ink Color	% Volatiles	% Solids	% Volatiles	% Solids
Black	4.1	95.88	0.17	99.83
Blue	4.7	95.26	0.10	99.88
Red	4.2	95.76	<0.01	100.10
Yellow	5.3	94.68	1.6	98.40
Average	4.6	95.40	0.77	99.55

shown in Table 8. Due to differences in make-ready and cleanup, comparisons between the two inks can not be made using these data. The main point of these data is that for each type of ink most solids (almost 90%) originated from the inks while over 99% of the volatiles originated from the cleaners. With petroleum inks

TABLE 7. RESULTS OF LABORATORY ANALYSIS TO DETERMINE SOLID AND VOLATILE COMPONENTS IN THE ROLLER AND BLANKET CLEANERS USED

Cleaner	Type	% Volatiles	% Solids
RBP #1	Roller	88	12.1
RBP #2	Roller	>99	0.07
Mix	Roller	>99	0.56
V120	Blanket	98	1.98
Clean Quick	Blanket	100	<0.01

about 99.4% of the volatiles were from the inks. For the soy inks, over 99.6% were from the inks. In longer print runs a greater percentage of volatiles would typically originate from the inks.

AIR EMISSIONS

The total mass of air emissions was estimated by assuming that it was equivalent to the volatile content of the materials used. This worst case assumption was made because of the impracticality of directly measuring the amount of emissions from the many sources on the press, the printed papers and the waste containers. It

TABLE 8. SOLID AND VOLATILE CONTENTS OF INKS AND CLEANERS USED FOR THE PETROLEUM AND SOY-BASED INK RUNS (g)

Parameter	Petroleum Print Run	Soy Print Run
Ink Solids	537.17	371.36
Cleaner Solids	64.78	48.64
TOTAL SOLIDS	**601.95**	**420.00**
Ink Volatiles	24.93	11.54
Cleaner Volatiles	3905.22	2992.76
TOTAL VOLATILES	**3930.15**	**3004.30**

was not practical to enclose the press, there were several other operating presses nearby, and air flow patterns in the room would likely bring some emissions from the other presses into the Miller press area. Ultimately most, if not all, the volatiles in the inks and cleaners will either evaporate, be discharged to the water or be containerized and sent to a landfill. These emissions will partially occur at the print shop, perhaps after shipment of the printed product, and at waste management facilities. The proportion of volatilization that will occur in any one place will vary by how the waste materials are managed. On an equivalent basis there were 0.39g/100 sheets printed of volatile emissions from the petroleum inks compared with 0.23g/100 sheets with the soy inks.

LIQUID WASTES

The washup tray wastes and inks cleaners on used rags are the two main liquid wastes from the printing press. None of these materials were spilled during the two runs. The ultimate fate of these wastes may not be to the water environment depending how they are managed. As described earlier, some of the components may continue to volatilize during storage or handling. Their final disposition may either be to a landfill, an incinerator or an industrial laundromat.

The practice used to clean the various rollers and blankets was to saturate several rags with each cleaner. These rags were used to wipe down the press. As a result, the rags contained a highly volatile mixture of inks and cleaners. Some of these cleaners and inks ended up in the washup trays in undeterminable proportions. Rather than measuring the rapidly changing amount of liquids on the rags immediately at the end of the print run, the rags were dried and the amount of dried solids on the rags was determined gravimetrically. The results were shown in Table 5. About 61 per cent more solids were on the rags used to clean the presses after the petroleum ink run. Since more inks and cleaners were used in the print run that used petroleum inks, it appears that much of these materials ended up on the cleanup rags. Since most of the solids came from the inks, a comparison can be made based on an equivalent number of pages printed. With petroleum inks 9.1g of solids per 100 sheets printed were generated compared with 7.1g of solids per 100 sheets with the soy inks. This is about 28% more solids with the petroleum inks.

The amount of liquids in the washup trays from this study was measured directly at the end of the print runs. These results were given in Table 5. Almost 10 per cent more liquids were generated in the washup trays from the petroleum ink run. The composition of this liquid was a mixture of inks and various cleaners. The proportion of each ink and each cleaner that ended up in these trays versus the rags (less the amount evaporated and on printed product) could not be measured.

The amount of each cleaner used to saturate the rags was not metered out precisely by the various press operators. There is considerable variability in the amount of cleaner used for the same job even by the same operator with the method employed at OPS. Differences between the two runs in the amounts of cleaner used were due to variability when pouring cleaners on the rags and not due to the type of ink being cleaned.

SOLID WASTES

The petroleum-based ink run was done first, and 1375 waste sheets were generated during make-ready of that run. The reverse side of 100 waste sheets were reused during make-ready for the soy ink print run.

This is the amount of solid waste generated directly during these print runs. Additional solid wastes that may be generated in printing include trimmings and excess number of pages printed to compensate for losses that may occur during folding, binding and any other final preparation steps. The amount of these wastes would not be affected by the type of ink used. In this case the difference in make-ready waste was due to problems with moisture in the paper at the beginning of the print run and not due to more difficulty with using the petroleum inks.

Press alignment and ink metering was automated for the press used in this study. Based on observations of manually operated presses at this and other facilities, automation or efficient press set-up results in less solid waste being generated during printing than does the choice of inks. Once operators are familiar with the use of either the petroleum or soy inks, then the amount of solid waste generated during make-ready will not be noticeably different. In both cases more waste paper might be generated on some jobs due to difficulties in obtaining acceptable colors or other print quality factors. In this regard, neither ink appears to have a clear advantage over the other.

COST COMPARISON

Cost factors that could be considered in comparing two options can be divided into four categories. These are: (1) direct costs such as materials, direct labor, utilities, equipment, and insurance; (2) indirect or hidden costs including monitoring expenses, reporting and record keeping, and permit requirements; (3) future liability costs such as remedial actions, personal injury, and property damage; and (4) less tangible costs such as consumer response, employee relations, and company image (American Institute for Pollution Prevention, 1993). In this study the main factor considered was the cost of raw materials. For all the other factors, there were either no measurable differences between the two types of inks used or they were not easily quantifiable. No equipment expenditures were required by OPS to switch from using petroleum to soy inks. The difference in the amount of labor involved in the two print runs was due to the problems with paper at the beginning of the first run and the fact that cleanup was more rigorous at the end of the second run. This difference was not due to the type of ink being used. Operating conditions of the press, such as temperature and speed, were the same for each ink so there was no difference in overall rate of production or utilities used because of the type of ink used. Insurance, monitoring requirements, reporting and recordkeeping, and permit requirements are the same for each type of ink. Any differences in future costs for remediation of waste disposal sites would be negligible. Health insurance costs might favor the use of soy inks because of reduced employee exposure to volatile chemicals. All the quantified cost factors are for the Miller TP 104 press only and not for the entire facility at OPS.

Since there are little to no perceived or real differences in most of the above factors, the less tangible benefits of using soy inks (company image as being environmentally friendly, improved employee relations due to a healthier working environment, and customer preference for products) are major factors considered by printers. If customer response to quality of product is negative, printers will not adopt a new ink. At OPS, their experience has been that customers find the quality of the product to be acceptable and many prefer to have their job printed with soy inks. A printing company also must consider the willingness of its press operators to switch to and use soy inks. At OPS there was some resistance to change at first. Formulations of soy inks in sheet-fed offset presses were new. In the past few years these formulations have improved and the press operators at OPS have gained the experience necessary to produce high quality images. Presently, the employees prefer to use soy inks on this particular press. A major reason for this is that the soy inks are very similar to work with and clean. If an alternative cleaner was used that took the operators longer or required more effort for the soy inks then there would be considerable resistance and cost. Some operators of old presses at OPS are not as accepting of the soy inks.

Typically the cost of soy inks is about 10% more than for petroleum inks. The purchase price of the raw materials (inks, cleaners and paper) for this print job at OPS does not vary by type of ink. However, costs do vary when the amount of materials that were used for printing with petroleum inks is compared to the cost of materials for printing with soy inks. The average purchase price for both the soy inks and petroleum inks is about $8.00 per pound (or $0.018 per gram). Actual costs, depending on the color and current price, range from about $4.00 to $12.00 per pound. The difference in the amount of ink used for acceptable product adjusted for differences in make-ready was 440.1 grams of petroleum ink versus 375.3 grams of soy ink. This gives an overall savings in ink used for the soy ink print run of $1.16. If the cost of soy ink had been 10% more, then printing with the soy inks would have cost about $0.50 less. This cost difference is not a major factor in ink selection. Labor, materials such as paper, equipment amortization, and utilities are higher costs. The portion of total printing costs from use of inks is usually very small.

The purchase prices of the cleaners are as follows: Clean Quick, $6.26/gal; V-120, $7.66/gal; RBP #1, $13.00/gal; RBP #2, $11.81/gal; and mix, $2.45/gal. When adjusted to the amount of acceptable product printed, the difference between cleaner costs for the petroleum and soy ink runs for this print job was only 5 cents (Table 9). This difference would have been greater if cleaning after the petroleum-based ink run had been more thorough.

DISCUSSION OF ADDITIONAL WASTE REDUCTION OPTIONS WITH AN OFFSET PRESS

There are two additional strategies or approaches that printers might use to reduce wastes from the sheet-fed off-set printing, both of which may involve additional capitol input for equipment. One strategy is to recover or reuse waste inks and cleaners that are produced. A solvent still could be used to recover chemicals from the washup tray wastes and possibly reuse those chemicals in formulating cleaners. Some large printers have reportedly adopted this approach. A second strategy is to reduce wastes produced by decreasing the excess amount of cleaners and inks used. Automatic blanket washers and automatic ink roller train systems reportedly can reduce material use and resulting volatile chemical emissions and liquid wastes.

Literature from Baldwin Graphics Products (Stamford, CT), one manufacturer of this equipment, claims that as little as 220 - 275 ml (8-10 ounces) of cleaning solvent can be used during a print run when the automated systems are in use. While this does not eliminate the need for hand cleaning, it does greatly reduce

TABLE 9. ESTIMATED COST OF CLEANER USED FOR EACH PRINT RUN AT OPS

Ink Type	Cleaner	Cost, $
Petroleum	V-120	3.38
	Clean Quick	2.64
	RBP #1	0.48
	RBP #2	0.70
	Mix	0.09
Total		7.29
Total (acceptable product)		5.71
Soy	V-120	2.18
	Clean Quick	1.92
	RBP #1	0.95
	RBP #2	0.60
	Mix	0.13
Total		5.78
Total (acceptable product)		5.67

the amount of cleaner required, and thus the emissions from the cleaners. Automated systems can also reduce employee exposure to potentially harmful substances. The print run monitored here required from 3.193 to 3.83 L of cleaners from start to finish. Thus, an automatic blanket washer could reduce cleaner use by about 90 per cent. Plus it could provide more controlled use of cleaners compared with the large variability inherent with manual cleaning. It should be noted that on some presses where these systems have been installed the operators actually increased use of the cleaners because even during a print run the blankets can be cleaned without stopping the press. Automatic ink handling systems allow this type of press to be operated with as little as 16 ounces of ink in the fountain, as opposed to 2.2 L (80 ounces) used without the automated system. That would result is about 80 per cent less ink usage.

The automatic blanket washer and ink handling systems also reduce make-ready and cleanup times, saving the press crew time and exposure to volatile compounds. Based on calculations performed by Baldwin Graphic Products, automatic blanket washers can save an estimated $37,777 per year with a return on investment of 2.26 years. Table 10 gives an estimate of the potential annual operating cost savings of utilizing the system on the Miller TP 104 press operation at OPS. Most of the savings would be expected in the cost of cleaners and in reduced cleanup time.

The differences between the manual system and the automatic blanket cleaner are estimated to be: 6oz of cleaner for manual system versus 2oz of cleaner for the automatic blanket cleaner, and an average wash time of 6 minutes for manual system versus 2 minutes for the automatic blanket cleaner. The 6oz and 6 minutes are estimates which were determined by OPS based on the average ounces of cleaner and time that it normally takes to wash the blankets.

The solvent cost in the calculation was $8.00 since this is the cost of the solvent which is recommended to be used with the automatic system. For both systems it was assumed that there were 150 blanket washes per day based on 6 blankets on the Miller TP104 press and these were washed an average of 25 times a day.

TABLE 10. ANNUAL COST COMPARISON OF UTILIZING AUTOMATIC BLANKET WASHERS

Cost Factors ($)	Manual System	Automatic Blanket Washer
Annual Costs		
Solvent	$ 20,530	$ 6,845
Rags	2,740	8,760
Time	90,340	60,225
Total	113,610	75,830

Other factors to consider in evaluating the economic benefits of automatic systems include capitol costs of the equipment, depreciation, and taxes. These factors can be evaluated in a simple analysis of payback period as shown in Table 11. One important factor not included in this analysis is operating costs for utilities and maintenance. Thus, the estimated payback period could be approximately 4 years. Factors at other printers could greatly reduce the payback time such as if installing such systems would eliminate the need to install pollution control equipment.

TABLE 11. ECONOMIC ANALYSIS OF AUTOMATIC BLANKET WASHER AT OPS

Annual Savings (Manual - Automatic)	$37,780
Installed Cost or Investment (Capitol Cost of Equipment)	$85,320
Annual Fixed Costs	
Depreciation (10% of investment)	8,532
Taxes and Insurance (1% of investment)	853
Net Savings (Annual Savings - Fixed Costs)	28,395
Net Savings After Taxes (48% Tax Rate)	14,765
Cash Flow (Net Savings After Taxes + Depreciation)	23,297
Payback Period In Years (Investment/Cash Flow)	3.66

SECTION 5

QUALITY ASSURANCE

The initial quality assurance project plan for this project had as the overall goal to quantitatively evaluate the amount of waste reduction (volume and toxicity) to all environmental media, and the economic factors, resulting from the use of soy ink and alternative cleaners in cooperation with the Office of Printing Services (OPS). At the time this project was conceived, the use of soy-based inks was novel and alternative cleaners were in the initial stages of development. Modifications have been made with respect to the original project plan because of changes made in the materials used by OPS between the initiation of the project and the actual data collection, and because of project design evaluation. OPS now uses the same cleaners for both soy-based and petroleum-based inks. Therefore, it was not possible to test different cleaners for each type of ink. Also, the original plan included testing the two types of inks and cleaners on two presses. That experimental design would have involved collecting data on four separate print jobs, each printing identical text on each side of a document. As it turned out, only one suitable print job came up during the time frame of this project.

Although significant modifications were made with the project design, efforts were made to ensure that the quality assurance objectives established for this project were not compromised. The specifications outlined in the quality assurance project plan were followed with respect to sampling and analytical procedures, instrument calibration, internal quality control checks, and data reduction, calculation, validation, and reporting. Table 12 gives an overview of the quality assurance objectives approved by USEPA for this specific project.

TABLE 12. QUALITY ASSURANCE OBJECTIVES

Measurement parameter	Precision	Accuracy	Completeness	Instrument detection limit	Range
Mass			90%	0.1g	0 - 12Kg
$\leq$ 1 g	$\pm$ 10%	90% - 110%			
$\geq$ 1 g	$\pm$ 10%	90% - 110%			

Data collected at the Office of Printing Services were mass measurements made on a Sartorius electronic balance (capacity 12kg $\pm$ 0.1 g). After transport from the Hazardous Materials Laboratory, the balance was calibrated using the internal calibration function and checked with Class S weights prior to commencement of data collection. Field samples were recorded on sheets with identifying data including date, press unit/station, ink type, ink color, and data recorder's initials.

The solid components in each ink and cleaner were measured at the Hazardous Materials Laboratory using a modification of test method number ASTM D 2369, the Standard Test Method for Volatile Content of Coatings (ASTM 1991). Three to four subsamples from each sample collected were analyzed and data were reported with a mean $\pm$ Relative Standard Deviation. Field samples were collected and recorded on a field sampling custody record which accompanied the samples through to completion of the analysis. The data were reviewed by the Laboratory Manager prior to release to the Principal Investigator.

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APPENDIX

TABLE A-1. RESULTS OF LABORATORY ANALYSIS OF CLEANER SAMPLES TO DETERMINE % SOLID COMPONENTS USING MODIFIED ASTM METHOD D-2369

Cleaner	Trial 1	Trial 2	Trial 3	Trial 4	Average	% Std. dev.
RBP #1	12.1	12.1	12.0	-	12.1	5.7
RBP #2	<0.01	0.28	<0.01	<0.01	0.07	13
Mix	0.35	0.58	0.78	0.52	0.56	32
V120	2.65	1.51	2.27	1.50	1.98	29
Clean Quick	<0.01	<0.01	<0.01	-	<0.01	0

TABLE A-2. RESULTS OF LABORATORY ANALYSIS OF INK SAMPLES TO DETERMINE % SOLID COMPONENTS USING MODIFIED ASTM METHOD D-2369

Ink	Trial 1	Trial 2	Trial 3	Trial 4	Average	% Std. Dev.
Petroleum Based Black	97.25	94.60	95.78	96.87	95.88	1.4
Petroleum Based Blue	94.93	95.03	95.83	-	95.26	0.5
Petroleum Based Red	94.37	94.55	99.12	95.01	95.76	2.4
Petroleum Based Yellow	95.09	94.81	94.15	-	94.68	0.5
Soy Based Black	99.71	100.3	100.0	99.31	99.83	0.4
Soy Based Blue	100.0	99.45	100.2	-	99.88	0.4
Soy Based Red	99.72	100.7	100.0	-	100.1	0.7
Soy Based Yellow	97.26	98.76	97.57	100.0	98.40	1.3

TABLE A-3. QUANTITY (g) OF RBP #1 CLEANER USED AT EACH PRESS UNIT FOR THE PETROLEUM AND SOY INK PRINT RUNS

Ink Color	Ink Type	Initial Weight (g)	Final Weight (g)	Cleaner Used (g)
Black	Petroleum	864.6	824.5	40.1
	Soy	824.5	745.7	78.8
Blue	Petroleum	852.0	807.2	44.8
	Soy	807.2	731.5	75.7
Red	Petroleum	894.1	864.6	29.5
	Soy	745.7	647.8	97.9
Yellow	Petroleum	944.4	909.3	35.1
	Soy	909.3	869.0	40.3

TABLE A-4. QUANTITY (g) OF RBP #2 CLEANER USED AT EACH PRESS UNIT DURING THE PETROLEUM AND SOY INK PRINT RUNS

Ink Color	Ink Type	Initial Weight (g)	Final Weight (g)	Cleaner Used (g)
Black	Petroleum	767.6	736.6	31.0
	Soy	736.6	693.1	43.5
Blue	Petroleum	696.1	661.6	34.5
	Soy	661.6	605.4	56.2
Red	Petroleum	843.4	767.6	75.8
	Soy	693.1	673.4	19.7
Yellow	Petroleum	754.3	657.7	96.6
	Soy	657.7	572.8	84.9

TABLE A-5. QUANTITY (grams) OF THE MIX CLEANER (H_20, ALCOHOL & LACTIC ACID) USED AT EACH PRESS UNIT DURING THE PETROLEUM AND SOY PRINT RUNS

Ink Color	Ink Type	Initial Weight (g)	Final Weight (g)	Cleaner Used (g)
Black	Petroleum	505.3	492.9	12.4
	Soy	492.9	465.0	27.9
Blue	Petroleum	481.5	447.7	33.8
	Soy	447.7	395.6	52.1
Red	Petroleum	524.8	505.3	19.5
	Soy	465.0	440.1	24.9
Yellow	Petroleum	469.1	407.6	61.5
	Soy	407.6	336.1	71.5