LOW-VOC, LOW TOXICITY CLEANUP SOLVENTS FOR SCREEN PRINTING: SAFER ALTERNATIVES

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EXECUTIVE SUMMARY

There are more than 16,000 screen printers in the U.S. and almost 2,000 of them are in California. The vast majority of screen printers are small businesses with fewer than 20 employees. Screen printers use various types of inks to print on a variety of substrates including fabric, paper, metal, glass, wood, ceramics and plastics. Some small screen printers print by hand but most commercial screen printers use automated presses.

During printing, screen printers use cleanup solvents to clean the excess ink from the screens. All screen printers remove the ink from the screens after printing when the screens are saved for the next run or recycled for reuse. The cleaners that are used today may contain toxic materials that pose a risk to workers and community members and virtually all of them are classified as VOCs that contribute to smog.

The South Coast Air Quality Management District (SCAQMD) regulates VOC emissions in four counties in southern California. One of the SCAQMD regulations specifies VOC limits for cleanup solvents used in screen printing. The VOC limit is presently set at 500 grams per liter. On July 1, 2006, the limit will be reduced to 100 grams per liter. Companies in Southern California must find alternatives that meet the much lower VOC level.

The Institute for Research and Technical Assistance (IRTA) is a nonprofit organization that assists companies and whole industries in finding safer alternatives in cleaning, adhesive, coating, dry cleaning and paint stripping applications. The South Coast Air Quality Management District (SCAQMD) contracted with IRTA to work with three screen printers to identify, test, develop and demonstrate alternative low toxicity, low-VOC cleanup materials. In an earlier project, sponsored by Cal/EPA's Department of Toxic Substances Control and U.S. EPA, IRTA worked with nine screen printers to demonstrate alternatives. In the SCAQMD project, IRTA worked with three textile printers, including Totally Ink, Applied Pressure and Powerhouse. The printers that participated in the two projects used a range of different inks and printed on a variety of different substrates. This report summarizes the results of both projects.

The low toxicity, low-VOC alternatives that were tested were of three types. First, water-based cleaners were tested in several facilities and found to be effective. Second, vegetable based cleaners composed of soy performed well for cleaning certain types of inks. Third, acetone, a chemical not classified as a VOC and low in toxicity, was blended with other materials and found to effectively clean traditional solventborne inks.

Table E-1 shows the 12 facilities that participated in the project. It also presents a description of the type of printing the facility does and the type(s) of inks used by each facility. Finally, it summarizes the alternative(s) that performed effectively in each of the participating facilities. Three of the companies, Owens-Illinois, Texollini and Powerhouse, elected to convert to the alternatives that were tested in the course of the project.

Table E-1
Participating Company Description and
Successful Safer and Low-VOC Alternatives

Company	Printing Description	Ink Type	Successful Alternatives
Owens-Illinois	Prints on plastic cosmetic Bottles	UV	Soy Based Cleaner
Southern California Screen Printing	Prints on paper and plastic	UV	Water-Based Cleaner, Soy Based Cleaner
Com-Graf	Prints on variety of different substrates	Solventborne	Soy/Acetone/Mineral Spirits Blend
Serendipity	Prints on variety of different substrates	Solvent and Waterborne	Acetone/Mineral Spirits Blend
Oberthur	Prints on plastic credit cards	Solvent and Waterborne	Acetone/Ethyl 3-ethoxy propionate Blend
Texollini	Prints on fabric	Waterborne	Water-Based Cleaner
Hino Designs	Prints on textiles	Plastisol	Water-Based Cleaner, Soy Based Cleaner
Quickdraw	Prints on textiles	Plastisol	Soy Based Cleaner, White Oil/Acetone/Mineral Spirits Blend
LCA Promotions	Prints on textiles	Plastisol	Soy Based Cleaner, Water-Based Cleaner, White Oil/Acetone/Mineral Spirits Blend
Totally Ink	Prints on textiles	Plastisol	Soy Based Cleaner, Water-Based Cleaners
Applied Pressure	Prints on textiles	Plastisol	Water-Based Cleaner
Powerhouse	Prints on textiles	Plastisol	Water-Based Cleaner

IRTA analyzed and compared the costs of the alternatives and the cleaners that are currently used by the facilities. In nine cases, the cost of using an alternative was lower or about the same as the cost of using the current cleaner. In three cases, the cost of using the alternative cleaner was higher than the cost of using the current cleaner.

The results of the project indicate that low-VOC, low toxicity alternatives are available and cost effective for screen printing facilities in California. Water-based cleaners, soy based cleaners and acetone blends which are lower in toxicity and low in VOC content perform well in removing the different types of ink used by the screen printing industry today.

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I. INTRODUCTION AND BACKGROUND

The printing industry is one of the largest manufacturing industries in the United States. The industry is dominated by small and medium-sized businesses, most of them with fewer than 20 employees. In 2002, according to the Bureau of Census, approximately 83 percent of the screen printing industry was comprised of small businesses. The Info USA Power Business Database estimates the number of screen printers in 2002 in the U.S. at 16,341. California has 1,886 screen printing establishments.

Volatile Organic Compound (VOC) emissions from solvent cleaning operations contribute significantly to the South Coast Air Basin's emission inventory. The South Coast Air Quality Management District (SCAQMD or District) periodically adopts an Air Quality Management Plan (AQMP). This AQMP calls for significant reductions in VOC emissions from cleaning and degreasing operations by 2010 to achieve attainment status.

The SCAQMD regulates VOC emissions from businesses located in the four county area including Los Angeles County, Orange County, San Bernardino County and Riverside County. One of the SCAQMD rules, Rule 1171 "Solvent Cleaning Operations," regulates the VOC content of screen printing cleanup solvents. The VOC content of screen printing cleanup solvents is currently set at 500 grams per liter. The District plans to reduce the allowed VOC content to 100 grams per liter on July 1, 2006. Lowering the VOC content to 100 grams per liter would reduce emissions of these solvents by about 1.3 tons per day. By July 1, 2006, screen printers in southern California must convert to alternative low-VOC cleanup materials.

The Institute for Research and Technical Assistance (IRTA), a nonprofit organization, was established in 1989 to assist industry in adopting safer alternatives to ozone depleting, chlorinated, other toxic and VOC solvents. IRTA staff have worked with hundreds of facilities in the South Coast Basin to identify, test and develop alternatives. IRTA runs and operates the Pollution Prevention Center (PPC), a loose affiliation of local, state and federal governmental organizations and a large electric utility.

The SCAQMD contracted with IRTA to work with three textile printers to test and demonstrate low-VOC alternatives that would meet the 100 gram per liter VOC limit. IRTA worked on three earlier projects that focused on finding alternative cleanup materials in screen printing. First, Cal/EPA's Department of Toxic Substances Control (DTSC), with DTSC and U.S. EPA Region IX funding, contracted with IRTA to work with screen printers to identify, test, develop and demonstrate alternative low-VOC, low toxicity cleanup solvents. Second, IRTA worked with U.S. EPA on a project that involved working with a few screen printers. Third, IRTA worked on an earlier project with SCAQMD that included screen printers. In the earlier SCAQMD project, IRTA was not able to complete the work with textile printing, one category of screen printing.

IRTA undertook the current SCAQMD project to conduct testing of alternatives with three additional textile printing companies. This document presents the results of the project sponsored by Cal/EPA's DTSC and U.S. EPA and the results of the testing with the three new textile printers.

Screen Printing

Screen printing is a short-run process that prints on almost any substrate including fabric, paper, leather, metal, glass, wood, ceramic and plastics. It is used for printing art prints, posters, greeting cards, labels, menus, program covers, wallpaper and textiles such as clothing, tablecloths, shower curtains and draperies. Some screen printing is done by hand with very simple equipment consisting of a table, screen frame and squeegee. Most commercial printing is performed on automated presses. One type of automated press uses flat screens that move in an indexed manner so that ink of different colors can be applied. Another type uses rotary cylindrical screens with the squeegee mounted inside the cylinder. The ink is pumped in automatically.

Screens are prepared before printing by the screen printers. The screens can be various sizes and they are generally made of polyester material with a wood or metal frame. A light sensitive emulsion is put onto the screen and it is cured with light. The emulsion forms a so-called stencil which serves as the pattern for printing. During printing, ink is forced through the screen and a pattern is printed on the substrate. The emulsion masks the part of the screen so that ink cannot pass through. Some companies also use a material called blockout to touch up the emulsion.

Most companies save the screens after a printing run so they can be used next time the customer orders a job. The emulsion is not removed from these screens and the screens are stored for future use. Some companies remove the emulsion each time the screen is used for printing.

Four types of inks are commonly encountered in screen printing. One type of ink is solventborne ink which is used by many printers. Another type of ink, called Plastisol ink, is used in textile printing applications; this ink is also solventborne. Textile printers account for about two-thirds of the screen printers. Some screen printers use ultraviolet (UV) curable ink which contains photoinitiators that are cured using light. Finally, a few screen printers use waterborne inks.

There are two places in the process where solvents are used to clean ink from the screens. During printing, many companies clean the screens periodically when the ink builds up. After printing when the screens are recycled or completely cleaned, solvents are used to remove the ink from the screens. Plain water or water-based cleaners are used to clean waterborne ink from the screens. Other materials are used to remove the emulsion, blockout and ghost image.

Participating Facilities

Nine facilities that have screen printing operations participated in the DTSC/EPA sponsored project and three additional facilities participated in the SCAQMD sponsored project. Table 1-1 shows a list of these facilities together with a description of the type of printing they perform and the type of ink they use. The results of the testing for the first nine facilities were reported in the final report for the DTSC/EPA project; the results for the last three facilities are reported here for the first time.

Table 1-1
Facilities Participating in Project

Company	Printing Description	Ink Type
Owens-Illinois	Prints on plastic cosmetic bottles	UV
Southern California Screen Printing	Prints on paper and plastic	UV
Com-Graf	Prints on variety of different substrates	Solventborne
Serendipity	Prints on variety of different substrates	Solvent and waterborne
Oberthur	Prints on plastic credit cards	Solvent and waterborne
Texollini	Prints on fabric	Waterborne
Hino Designs	Prints on textiles	Plastisol
Quickdraw	Prints on textiles	Plastisol
LCA Promotions	Prints on textiles	Plastisol
Totally Ink	Prints on textiles	Plastisol
Applied Pressure	Prints on textiles	Plastisol
Powerhouse	Prints on textiles	Plastisol

The facilities have a variety of different processes. Some, like Oberthur and Texollini manufacture goods and perform screen printing as part of their operations. Six of the facilities, Hino Designs, Quick Draw, LCA Promotions, Totally Ink, Applied Pressure and Powerhouse, are small textile printers who primarily print on T-shirts. Com-Graf prints on a variety of different products including glass and ceramics. Serendipity is a small one-person shop that does various printing jobs. Owens-Illinois prints on a range of different plastic cosmetic bottles. Southern California Screen Printing prints very large plastic and paper banners. Plastisol ink is used by the six T-shirt printers. UV curable ink is used by two of the participating facilities. Three facilities use waterborne ink, three facilities use more traditional solventborne ink.

Project Approach

The first step in the project was to visit each of the participating facilities. During these visits, IRTA toured the facility and focused particularly on the screen printing process. IRTA discussed the substrates and ink types used by each facility. IRTA also discussed the types of emulsions and blockouts used by the facilities. These are the parameters that affect the type of cleaner that can be used. IRTA requested a sample of ink or inks from the facilities.

The second step in the project was to perform preliminary tests at the IRTA office using the ink and several alternative cleaning agents. At this stage, IRTA wanted to screen alternative cleaning materials to see if they could clean the ink. IRTA obtained a typical screen from a screen printer and this screen was used in the preliminary testing. The ink was applied to the screen and different cleaning agents were rubbed on the screen with a wipe cloth to determine if they could effectively remove the ink. This test procedure allowed IRTA to determine which alternatives might be effective in cleaning ink at each facility.

The third step in the project was to visit the facilities and conduct initial tests with the alternatives that appeared effective in the preliminary testing to clean the ink in the screen printing process. The initial testing generally involved limited testing by hand cleaning screens that did not need to be saved for a future job. Some of the alternative cleaners can remove emulsion or blockout, depending on the type of emulsion or blockout used by the facility. Most facilities do not want the emulsion or the blockout to be removed so they can save the screens for the same customer with future jobs.

The initial facility testing generally involved testing two to 15 cleaning alternatives that have low-VOC and are relatively low in toxicity. If a cleaning agent cleaned the ink effectively but removed the emulsion or the blockout in cases where the facilities wanted to preserve the screen, it was eliminated from consideration. In almost all cases, IRTA tested the alternatives in the same manner the facility used the current cleaning agent. In some cases, however, it was necessary to modify the conditions. Water-based cleaners work much more effectively when they are heated and the initial facility testing was generally performed with a heated cleaner.

The fourth step in the project was to perform more extensive or scaled-up testing of the alternative cleaning agents that appeared to effectively remove the ink. IRTA provided the facilities with a week's supply or more of the cleaning agents so they could test them under production conditions. In some cases, IRTA provided equipment to the facility for the scaled-up testing which lasted for several weeks.

The fifth step in the project was to analyze and compare the cost and performance of the alternative and currently used cleaners. Section II of this document presents this analysis for the twelve facilities participating in the project.

Current Cleanup Solvents

Solvents used by the screen printing industry for cleanup in the U.S. include mineral spirits, methyl ethyl ketone, toluene, xylene, glycol ethers, terpenes, heptane and hexane. All of these solvents are classified as VOCs and many of them are toxic. Mineral spirits contain trace quantities of benzene, toluene and xylene. Benzene is an established human carcinogen; toluene and xylene are listed on California's Proposition 65. Hexane causes peripheral neuropathy, a nervous system disease.

SCAQMD is concerned about the VOC emissions from the solvents. The DTSC/EPA project sponsors were concerned about VOCs and exposure of workers and community members to the cleanup materials. The aim of the project was to identify, develop, test and demonstrate low-VOC, low toxicity alternative cleanup materials.

Alternative Cleanup Materials

The alternative low-VOC, low toxicity cleanup materials IRTA tested during this project can be classified into three categories. The first category is water-based cleaners. The second category is solvents that are exempt from VOC regulations. The third category is methyl esters which are vegetable based cleaners with a very low VOC content. Each of these categories of cleaners is discussed in more detail below.

Water-Based Cleaners. These cleaners generally contain a certain amount of water. They are sometimes diluted further with water when they are used for cleaning. Some water-based cleaners are based on surfactants; others contain a small amount of solvent. Water-based cleaners are most applicable for cleaning the plastisol ink used by the textile printers or ultraviolet (UV) curable ink used by some printers.

IRTA tested one water-based cleaner, called Ardrox 405-V and made by Chemetall Oakite, at two textile printing facilities. Both Hino Designs and LCA Promotions tested the water-based cleaner in a heated parts cleaner at 50 percent concentration. This water-based cleaner cleaned the ink effectively when the screens were being recycled.

IRTA tested another water-based cleaner, called Experimental Commercial Printing Cleaner NP 2520, which is made by Mirachem. This cleaner was tested at Southern California Screen Printing in a recirculating brush application system at full concentration. It worked very effectively in cleaning the UV curable ink when the screens were being recycled. The same water-based cleaner was tested at three textile printing facilities, Totally Ink, Applied Pressure and Powerhouse. At Totally Ink, the cleaner was applied by hand in concentrate form; at Applied Pressure and Powerhouse, the cleaner was used in a heated parts cleaner at 50 percent concentration. Powerhouse has since converted to this cleaner and has been using it for several months.

IRTA tested a third water-based cleaner, called GD 1990 and made by Brulin, during the project. The cleaner worked effectively for cleaning the semi-cured water-based ink at Texollini. The company converted to the cleaner and it is used in a high pressure spray process at about one-third concentration.

Exempt Solvents. There are a number of solvents that have been specifically deemed exempt from VOC regulations by U.S. EPA and local California air districts. Some of these contribute to ozone depletion and their production has been banned. The use of others, perchloroethylene and methylene chloride, is severely restricted because they are classified as carcinogens. Still others, one of the volatile methyl siloxanes and parachlorobenzothrifluoride, have potential toxicity problems.

One solvent that is exempt from VOC regulations was tested during the project. Acetone is an aggressive solvent that is very low in toxicity compared to other organic solvents. It evaporates readily and its disadvantage is its low flash point. IRTA tested acetone extensively during this project and it is a very effective ink cleaner.

Acetone evaporates too quickly to effectively remove ink from the screens when it is used by itself. When IRTA tested acetone during this project, it was combined with small quantities of other VOC solvents to prevent such rapid evaporation. A blend of acetone was tested for on-press cleaning at three printers, Hino Designs, Quick Draw and LCA Promotions. It effectively cleaned the ink at two of these facilities. An acetone blend was also tested at Com-Graf, Oberthur and Serendipity and it worked effectively on the ink at those facilities.

Methyl Esters. This class of chemical generally contains methyl esters that have a 16 to 18 carbon chain length. Materials like soy, canola oil, rape seed oil and coconut oil are composed of methyl esters. These materials clean most types of inks very effectively. During this project, IRTA relied heavily on soy based cleaners and soy was selected because it is more widely available and lower cost than some of the other methyl esters. Several different formulations were tested for VOC content by SCAQMD and the VOC content ranged from five to 25 grams per liter.

Two soy based cleaners were tested with the six of the textile printers. One of the cleaners, called Soy Gold 2000 and made by Ag Environmental, effectively cleaned the plastisol ink. A second soy based cleaner, designed to be rinsed more easily, called Soy Gold 2500, was effective at ink removal at Totally Ink, Applied Pressure and Powerhouse. Use of the soy cleaners did, however, require an additional rinsing step for the textile printers. Soy cleaners are oily and they must be rinsed before the screens are ready for printing. Soy Gold 2000 was also effective for cleaning the UV curable ink at Owens-Illinois and the company converted their operation to use the vegetable based cleaner. Another soy based cleaner, called Autowash #3 and made by Seibert, was tested for cleaning the UV curable ink at Southern California Screen Printing. This cleaner worked almost as effectively as the current cleaner at that facility.

Cleaner Performance

Performance of the alternative cleaning agents at each facility was evaluated on a case-by-case basis. In each instance, the plant personnel provided information on their requirements for the cleaning process. In all cases, it was important for the cleaning agent to effectively clean the ink from the screens in a reasonable period of time. The facility personnel were the judges of which cleaners cleaned effectively. In addition, when cleaners were tested during printing, IRTA insisted that the facility print after cleaning to make sure the print quality was acceptable.

Cost Analysis

IRTA performed cost analysis for each of the alternatives that was successfully tested at each of the facilities participating in the project. The types of costs that were evaluated included:

- capital cost
- cleaner cost
- labor cost
- utilities cost
- disposal cost

These costs were evaluated and compared when the costs were different for the current solvent and the alternative cleaners.

In some of the cases, it was assumed that there would be a capital equipment requirement. In these instances, the cost of the capital equipment was spread over a 10 year period, which was assumed to be the life of the equipment. The interest rate for the cost of capital was assumed to be four percent.

In virtually all cases, there was a difference in the cost of the current solvent and the cost of the alternative cleaner. In some cases, there was a difference in labor costs and, in these instances, the different costs were compared. In a few cases, there was a difference in electricity costs and these were noted and compared. Finally, in some instances, there was a difference in disposal costs and these were analyzed where appropriate.

Report Organization

Section II of this report provides detailed information on the analysis that was performed for each of the companies participating in the project. The cost of the current and alternative process was evaluated and compared. Section III summarizes the results of the tests and demonstrations at the facilities. Appendix A includes MSDSs for the alternative products that were tested or adopted by the participating facilities. Appendix B provides the stand alone case studies for three of the facilities that opted to convert to alternatives.

II. ANALYSIS OF THE ALTERNATIVE CLEANING AGENTS

This section presents analysis of the performance and cost of the alternative cleaning agents that were tested during the project. It provides a description of each of the facilities where the testing was conducted, the cleaning agents that are used currently, the alternatives that were tested and the alternatives that were most effective. It also provides a cost comparison of the current and alternative cleaners. The alternative cleaners were tested for a few weeks in most of the facilities so it is unknown whether other problems would arise if they were tested for a longer period. The alternative cleaners have been used for a much longer period, for more than a year, at two facilities, Owens-Illinois and Texollini. These two facilities elected to convert to the alternatives. At three of the textile printing facilities, the cleaners were tested for at least a month; in one case, Powerhouse, the company decided to convert to the alternative and has been using it for several months.

Owens-Illinois

The Owens-Illinois Plastics Group operates a manufacturing facility in La Mirada, California. The company manufactures plastic cosmetic bottles for various types of products like shampoo and other personal products for a number of customers. Owens-Illinois has several extrusion and blow molding machines that are used to make the bottles. The company uses a range of plastic materials including HDPE, PET, LDPE, PVC and polypropylene. The bottles have various shapes including cylinders and ovals.

Owens-Illinois has several automated in-line decorating machines that are used to screen print on the plastic bottles. For a number of years, the company has exclusively used ultraviolet (UV) curable inks. The machines apply one color of ink to the bottle as it passes through the ink delivery system. Some of the bottles require five colors so they pass through five screens in the machine, each with one color. The bottles pass under a screen and squeegees applied to the top of the screen force the ink through the screen to color the pattern on the bottles. After the ink is applied, the bottles pass through an ultraviolet light which cures the ink. A picture of the process is shown in Figure 2-1.

Owens-Illinois performs two types of cleaning. Workers monitor the screens at the machines. Periodically, when the screens are contaminated, the worker uses a cleaner on a rag to wipe the excess ink from the lower part of the screen; this is in-process cleaning. After the run, the screens are removed from the machine, workers remove the ink from the top and bottom of the screens and they are processed further so they can be reused.

IRTA began working with Owens-Illinois on a project sponsored by the South Coast Air Quality Management District (SCAQMD). One of the SCAQMD regulations, Rule 1171, specifies that the VOC content of the cleaners used for screen printing cleanup have a VOC content of 100 grams per liter or less beginning in July of 2006. Owens-Illinois was using a high VOC cleaner and IRTA worked with the company to test alternatives that met the 100 gram per liter future VOC limit.

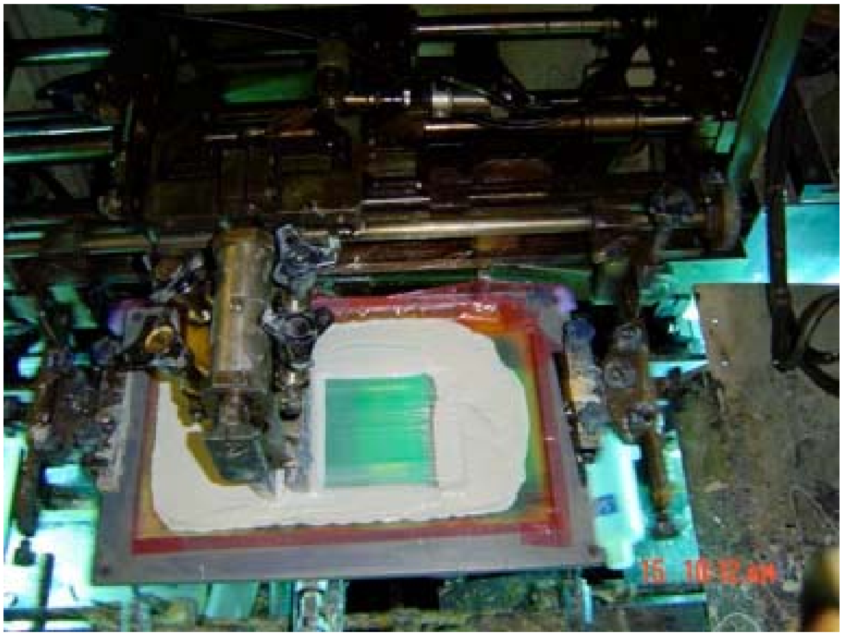

Figure 2-1. Printing Process at Owens-Illinois

In preliminary tests, IRTA found that high soy content cleaners cleaned Owens-Illinois' ink very well. IRTA performed scaled-up testing of one of the cleaners, Soy Gold 2000, at the facility. SCAQMD tests determined that the VOC content of this cleaner is less than 20 grams per liter which easily meets the future effective VOC limit. This product can be rinsed with water which is necessary for recycling the screens. After successful on-site testing, IRTA provided five gallons of the alternative cleaner to the facility for further testing. The results indicated that the cleaner performed well for both the in-process cleaning and the cleaning at the end of the process. An MSDS for the cleaner is provided in Appendix A.

IRTA followed up with Owens-Illinois in the current project and the company had converted to the alternative soy based cleaner. The cleaner has been successfully used for about a year. One advantage of the alternative cleaner is that it protects the emulsion which forms the pattern on the screen better than the high VOC cleanup solvent used in the past.

The only element in the cost that has changed with the adoption of the new cleaner is the price of the cleaner. Owens-Illinois uses about 15 gallons of cleaner per week under normal production conditions. The cost of the high VOC solvent is $13 per gallon. On this basis, the annual cost of using the high VOC solvent was $10,140. The cost of the soy alternative cleaner is less, at $10.90 per gallon. The same amount of the new cleaner is used so the annual cost for cleaning now amounts to $8,502.
Table 2-1 shows the annualized cost comparison for cleaning with the high VOC cleaner and the soy based cleaner for Owens-Illinois. The company reduced their costs by about 16 percent through the conversion.

Table 2-1
Annualized Cost Comparison for Owens-Illinois

	High VOC Cleaner	Soy Cleaner
Cleaner Cost	$10,140	$8,502
Total Cost	$10,140	$8,502

A stand alone case study for Owens-Illinois is shown in Appendix B.

Southern California Screen Printing

Southern California Screen Printing (SCSP) is located in Fontana, California. SCSP has six-color presses that provide in-line printing capability. The company prints high quality, high volume, large format work and their customers include the movie and advertising industries. Products printed by SCSP include very large banners, posters and bus advertising. SCSP uses UV curable ink for all of their operations. The screens used by the company for printing are very large, perhaps 15 feet long and seven feet high.

At the end of the screen printing process, SCSP must remove the ink from the screens. Currently the company has a large bay where the ink removal and other screen recycling operations occur. A picture of the cleaning bay is shown in Figure 2-2. SCSP, for several years, has used a high VOC glycol ether cleaner. The VOC cleaner is applied using a pump attached to a brush for scrubbing the screens. The cleaner is applied to only one side of the screen except in the case of black ink. When black ink is used, both sides of the screen must be cleaned to remove the ink. After the ink is cleaned, the stencil on the screen is removed and rinsed. The ghost image on the screen is then removed, the screen is rinsed again and then is vacuum dried.

IRTA conducted screening tests on SCSP's ink and found several alternatives that might be suitable. IRTA tested these alternatives by hand cleaning screens at SCSP. The results of this testing indicated that only one cleaner, Seibert Autowash #3, was effective in cleaning the ink. The cleaner is a blend of soy methyl esters and surfactants. An MSDS for the cleaner is shown in Appendix A. At a later time, IRTA identified a new water-based cleaner that cleaned the ink very well. This cleaner was also tested by hand on the screens at SCSP and it was effective in cleaning the ink. An MSDS for the water-based cleaner, called Mirachem Experimental Commercial Printing Cleaner NP 2520, is also shown in Appendix A.

IRTA arranged for scaled-up testing at SCSP of the soy based product and the water-based product. IRTA provided the company with 10 gallons of each formulation. The soy based cleaner worked acceptably but more labor was required. The water-based cleaner worked well and no additional labor was required.

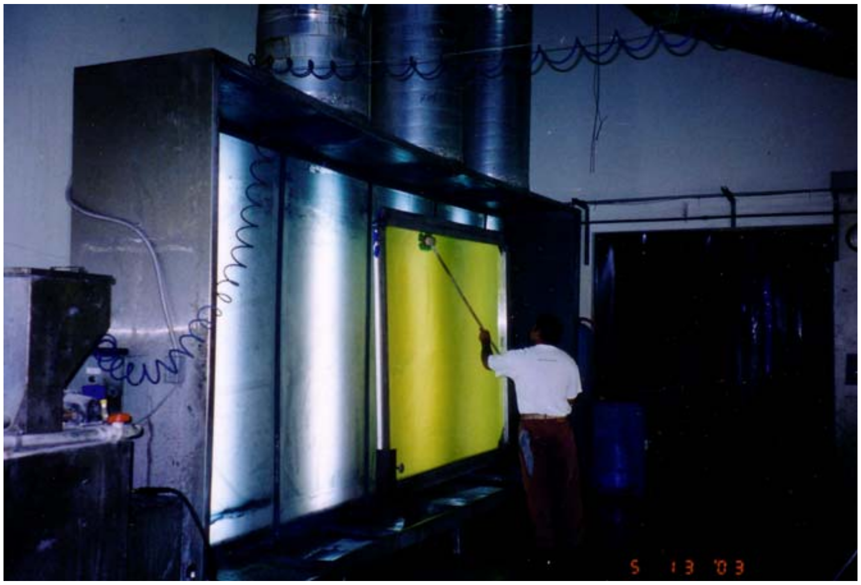

Figure 2-2. Cleaning Bay at Southern California Screen Printing

IRTA analyzed the costs of the alternatives and compared them to the costs of the current cleaner. SCSP uses 55 gallons per month of solvent and the cost of the solvent is $12.60 per gallon. The annual solvent usage is 660 gallons and, on this basis, the annual cost of the cleaning solvent is $8,316. The cost of the soy based alternative is $7 per gallon. The cost of the water-based cleaner, which is not yet commercialized, is estimated by the supplier at $12.50 per gallon. Assuming the same amount of the alternative cleaners would be required, the annual cost of the soy product would be $4,620 and the annual cost of the water-based alternative would be $8,250.

SCSP has one worker who spends seven hours per day cleaning screens. The worker's labor rate is $20 per hour. Assuming there are 260 working days per year, the annual labor cost for the cleaning process amounts to $36,400.

SCSP provided estimates of the labor breakdown for the cleaning process. The worker spends 20 percent of his time on ink removal, 20 percent of his time on stencil removal and rinsing, 20 percent of his time on ghost image removal, 13 percent of his time on final rinsing and seven percent of his time on the vacuum drying operation. For the cost analysis, it was assumed that the worker would spend twice the time when the alternative soy based cleaner was used on the ink removal part of his job. On this basis, use of the soy based cleaner would add 1.4 hours of work per day to the cleaning process. The annual labor cost would amount to $43,680. In the case of the water-based cleaner, the labor would be the same as with the current cleaner.

Table 2-2 shows the annualized cost comparison for the current high VOC cleaner, the soy based alternative and the water-based alternative. The lowest cost option is use of the water-based cleaner. It is slightly less costly than use of the current VOC solvent. The cost of using the soy based cleaner is eight percent higher than the cost of using the

VOC solvent. The soy based cleaner is lower in cost than the VOC solvent but the labor cost increase raises the total cost of using the alternative above the cost of using the VOC solvent.

Table 2-2
Annualized Cost Comparison for Southern California Screen Printing

	Current VOC Cleaner	Soy Based Cleaner	Water-Based Cleaner
Cleaner Cost	$8,316	$4,620	$8,250
Labor Cost	$36,400	$43,680	$36,400
Total Cost	$44,716	$48,300	$44,650

Com-Graf, Inc.

Com-Graf is located in Torrance, California. The company uses a variety of inks to print with fine mesh screens on various items including bottles and cups. The company specializes in printing on very difficult items like the surface of a walnut to a multi-angled chassis. Most of the ink used by Com-Graf is vinyl but the company also uses enamel and epoxy inks for printing. The cleaner currently used by the company is a high VOC material.

IRTA conducted preliminary testing with the owner of Com-Graf. A variety of alternatives were tested including a soy based cleaner, a white oil and a blend of acetone an mineral spirits. IRTA also performed testing with the Com-Graf workers during production. IRTA tested various blends of soy, acetone and mineral spirits. The blend that worked best was composed of 80 percent acetone, 10 percent Soy Gold 2000 and 10 percent mineral spirits. IRTA provided the company with larger quantities of the blend and it was tested for a longer period. The workers indicated that it performed well and that no additional labor was required to use the alternative. MSDSs for acetone, Soy Gold 2000 and the mineral spirit, called VM&P, are shown in Appendix A.

Com-Graf uses 55 gallons per month or 660 gallons per year of the high VOC solvent. The cost of the cleaner is $486 per drum or $5,832 per year. IRTA estimated the cost of the low VOC alternative from the cost of the individual components in the blend. The cost of Soy Gold 2000 is $9 per gallon. The cost of acetone is also $9 per gallon and the cost of mineral spirits is $6 per gallon. The cost of the blend, based on these costs, is $8.70 per gallon. Assuming the same usage rate for the alternative as for the high VOC cleaner, the annual cost of the alternative is $5,742.

Table 2-3 shows the annualized cost comparison for Com-Graf. The cost of using the alternative cleaner is slightly lower than the cost of using the high VOC cleaner.

Table 2-3
Annualized Cost Comparison for Com-Graf

	High VOC Solvent	Soy/Acetone/Mineral Spirits Blend
Cleaner Cost	$5,832	$5,742
Total Cost	$5,832	$5,742

Serendipity

Serendipity is a small specialty screen printing facility located in Santa Fe Springs, California. The company prints on a range of substrates including wood and metal items and skateboards with solventborne ink including epoxy and flat fabrics with water-based ink. The owner performs all of the operations.

Each time a screen is used, it is recycled. The ink and the stencil are removed. The owner uses a glycol ether followed by lacquer thinner to clean the screens.

IRTA conducted preliminary testing and identified various alternatives that might be suitable for cleaning the screens. IRTA tested the most promising alternatives at Serendipity on a clear solventborne ink, an epoxy ink and an ink designed to print on plastic. The alternative that worked best was a blend of 92 percent acetone and eight percent mineral spirits. IRTA provided Serendipity with larger quantities of the cleaner and it was tested for a few months. The owner indicated that it turned the emulsion white but this had no effect on the screen when it was recycled and reused. The cleaner effectively cleaned the ink. MSDSs for acetone and VM&P mineral spirits are shown in Appendix A.

Serendipity uses one gallon of cleaner every two months or six gallons per year. The cost of glycol ether is about $10 per gallon and the cost of lacquer thinner is about $6 per gallon. Assuming half the cleaner used currently is glycol ether and half is lacquer thinner, the cost of the VOC cleaners is $48 per year. The cost of the alternative low VOC cleaner is $54 per year based on a cost of $9 for acetone and $6 for mineral spirits. The owner indicated there are no labor differences in using the alternative cleaner.

Table 2-4 shows the annualized cost comparison for the high and low VOC cleaning formulations. The cost of using the low VOC cleaner is 13 percent higher than the cost of using the glycol ether and lacquer thinner.

Table 2-4
Annualized Cost Comparison for Serendipity

	Glycol Ether/ Lacquer Thinner	Acetone/Mineral Spirits Blend
Cleaner Cost	$48	$54
Total Cost	$48	$54

Oberthur Card Systems

Oberthur Card Systems is located in Rancho Dominguez, California. The company has several lithographic presses and two automated screen printing presses for printing on plastic used to make credit cards of all types. A picture of one of the screen printing presses is shown in Figure 2-3.

Figure 2-3. Automated Printing Press at Oberthur

In the screen printing operation, Oberthur uses both waterborne inks and solventborne inks. The company uses plain water to clean the water-based inks and has historically used a VOC solvent for cleaning the solventborne inks. As part of a project sponsored by U.S. EPA and Cal/EPA's Department of Toxic Substances Control, IRTA worked with Oberthur to identify, develop and test alternative low-VOC cleaners. SCAQMD Rule 1171 requires cleanup materials used in screen printing to have a VOC content of 100 grams per liter by July 1, 2006 and IRTA tested materials that would meet this level.

IRTA obtained samples of Oberthur's solventborne screen ink for preliminary testing. The tests indicated that soy based cleaners and acetone performed well. Over a several month period, IRTA worked with Oberthur to test a variety of cleaners. The soy based cleaners cleaned the ink effectively. They left an oily residue on the screens that was not absorbed by the plastic substrate, however, and the printing was not acceptable. It became clear that soy based cleaners even in low concentrations in the formulation could not be used. IRTA then tested a number of different formulations based on acetone. The best performing acetone formulation was composed of about 88 percent acetone and 12 percent ethyl 3-ethoxy propionate (EEP) by weight. This cleaner has a VOC content less than 100 grams per liter. MSDSs for acetone and EEP are shown in Appendix A.

IRTA conducted testing with the blend with Oberthur and it appeared to perform well. More of the alternative cleaner was required. IRTA provided five gallons of the blend to Oberthur for scaled-up testing and the company tested the cleaner. It performed effectively but the workers found that more of the alternative cleaner was necessary.

Oberthur uses 150 gallons of the VOC cleaner annually in the screen printing cleanup. The cost of the cleaner is $20.50 per gallon. On this basis, the cost of the cleanup solvent is $3,075 annually. For the alternative cleaner, IRTA assumed that 50 percent more would be required. This indicates that Oberthur would use 225 gallons of the acetone/EEP blend annually. Although this blend is not yet a commercial product, the blender estimates that the cost of the cleaner would be $7.28 per gallon. The annual cost of the alternative cleaner, taking into account the higher use level, is $1,638.

Table 2-5 shows the annualized cost comparison for the current VOC cleaner and the alternative cleaner for Oberthur. The values show that conversion to the alternative would reduce Oberthur's cleaning cost substantially, by 47%. Even if Oberthur required twice as much of the alternative cleaner as the current cleaner, the annual cleaning cost would still be much lower at $2,184 than the current cleaning cost.

Table 2-5
Annualized Cost Comparison for Oberthur

	Current VOC Cleaner	Alternative Cleaner
Cleaner Cost	$3,075	$1,638
Total Cost	$3,075	$1,638

Texollini

Texollini is a knitting mill located in Long Beach, California. The company provides fabric development, knitting, dying, finishing, fabric print design and printing capabilities. Part of Texollini's operations involve screen printing on fabrics the company makes for their customers. A picture of the company's screen printing system is shown in Figure 2-4.

Texollini uses water-based inks exclusively for their screen printing operations. The water-based inks are applied on a conveyor line and the ink is cured in an oven. The screens are on a cylinder on the conveyor line. They are removed and cleaned using cold water in an automated system. In certain cases, the ink dries on the screen and cannot be

Figure 2-4. Printing Operation at Texollini

removed with water. The company cleaned these screens with a VOC solvent using a hand-held spray wand.

IRTA conducted preliminary testing with Texollini's ink and identified several water-based cleaners that cleaned the ink effectively. Three of the water-based cleaners were tested in the hand-held spray cleaner. All three cleaners were more effective in cleaning the ink than the VOC solvent. IRTA provided larger quantities of the cleaner that performed the best for scaled-up testing. After three months of testing, Texollini decided to convert to the alternative cleaner. An MSDS for the cleaner, called Brulin GD 1990, is shown in Appendix A.

Texollini used 132 pounds of the VOC cleaner per year at a cost of 89 cents per pound. The annual cost of the cleaner amounted to $117. Texollini uses the water-based cleaner in a 25 percent concentration with water. Total annual usage is 41 pounds per year. Assuming a density for the cleaner of nine pounds per gallon and a price of $12.75, the annual cost of the alternative water-based cleaner is $58.

When the VOC solvent was used, Texollini had one employee who spent 1.5 hours per week cleaning ink from the screens. Assuming a labor rate of $10 per hour, the labor cost for cleaning with the VOC solvent was $780 per year. Less labor is required with the water-based cleaner. One employee now spends about one-half hour per week in cleaning. This amounts to an annual labor cost of $260.

The spray applicator requires 120 volts and two amps which translates into 0.24 kW per hour. With the VOC solvent, the spray wand was used for 78 hours a year. Assuming an electricity cost of 15 cents per kWh, the annual electricity cost was about $3 per year. With the water-based cleaner, the spray wand was used for less time, 26 hours per year. Again, assuming an electricity rate of 15 cents per kWh, the annual electricity cost is now $1 per year.

Table 2-6 shows the annualized cost comparison for Texollini. The company reduced their cleaning cost by 65 percent by converting to the water-based cleaner.

Table 2-6
Annualized Cost Comparison for Texollini

	VOC Solvent	Water-Based Cleaner
Cleaner Cost	$117	$58
Labor Cost	$780	$260
Electricity Cost	$3	$1
Total Cost	$900	$319

A stand alone case study for Texollini is presented in Appendix B.

Hino Designs

Hino Designs is located in Gardena, California. The company is a textile printer that develops and prints custom designs, primarily on T-shirts. Hino has one manual press and one automated press.

The company uses a VOC solvent for cleaning the screens during printing and after printing when the screens are recycled. During in-process cleaning, the cleaner is applied by hand with wipes. During final cleaning, Hino uses a recirculating cleaning system with a pump and brush to clean the screens. Between 30 and 40 screens are cleaned each week.

IRTA conducted preliminary testing with Hino by hand cleaning screens with various cleaners to decide which ones should be tested. The cleaners had to clean the ink well and they also had to leave the emulsion intact so Hino could save the screens for printing in the future. One of the cleaners, Mirachem Pressroom Cleaner, removed the emulsion when it was heated. Three other cleaners that did not remove the emulsion were also tested.

The best alternative cleaner in the screening tests was Soy Gold 2000, a vegetable based cleaner. An MSDS for this cleaner is shown in Appendix A. IRTA provided Hino with a parts cleaner containing the soy and it was tested for several weeks for cleaning the screens after printing. The soy cleaned the ink very well but it caused a problem with the screen tape. This tape is pulled off after printing and it leaves a residue. With Hino's VOC cleaner, the residue is simply left in place. The soy liquefied the tape adhesive residue and Hino was concerned that this would cause a problem when the company tried to reapply the emulsion. Hino did apply emulsions to about 60 screens with no problem but the company was concerned that there could be a problem in the future. The residue from the tape could be cleaned off with the soy but this would require increased labor. The soy also needed to be rinsed which was an additional step in the process.

IRTA tested another cleaner, a water-based cleaner called Super Scrub, in the parts cleaner at a concentration of one-third. This cleaner did not clean the ink effectively enough. IRTA increased the concentration to 50 percent but the cleaner did not perform as well as the current VOC cleaner.

IRTA tested a third cleaner, a water-based cleaner called Ardrox 405-V, at one-third concentration in the parts cleaner. An MSDS for this cleaner is provided in Appendix A. It did not clean aggressively enough so IRTA increased the concentration to 50 percent. This cleaner cleaned the ink as effectively as the VOC solvent. The operator, however, did not like the smell. IRTA added a fragrance to the cleaner and this improved the situation somewhat.

For the in-process cleaning, IRTA tested several alternatives. Hino is using an emulsion that is removed by many solvents. IRTA identified another emulsion that was solvent and water resistant. IRTA provided Hino with a sample but Hino did not test it during the project. IRTA did not identify an alternative for in-process cleaning at Hino.

IRTA analyzed and compared the cost of using the VOC solvent with the cost of using the soy and the Ardrox 405-V at the end of the printing process. Hino purchases about 60 gallons per year of the VOC cleaning solvent. The owner estimates that 60 percent of the solvent is used for in-process cleaning and 40 percent is used at the end of the printing cycle. The cost for five gallons of the cleaning solvent is $62.50. The in-process solvent cost is $450 annually. The cost of the solvent for cleaning after printing is $300 annually.

The operator that performs the cleaning at the end of the printing process spends about eight hours per week cleaning. Assuming the cleaning is performed 52 weeks per year and assuming Hino's labor rate of $7.50 per hour, the labor cost with the VOC solvent amounts to $3,120 annually.

Hino pays an electricity cost for using the pump on the cleaning system. IRTA estimates that the annual electricity cost related to the pump is $10. This is based on the electricity cost of a parts cleaner operating 1.6 hours per day.

Hino could use the soy cleaner in the current cleaning system. Assuming the use of the soy would be the same as the use of the VOC solvent, Hino would require 24 gallons of soy annually. At a cost of $9 per gallon for the soy, the annual cleaner cost would amount to $216. Use of the soy would require an additional one-half hour each week for the rinsing. On this basis, the labor cost with the soy would be $3,315. The electricity cost for using the soy is the same as the cost with the VOC solvent.

The Ardrox 405-V, like other water-based cleaners, needs to be heated to clean more effectively. Hino would need to purchase a heater for use with their cleaning system to use this cleaner. Assuming a heater cost of $400, a cost of capital of four percent and a useful life of 10 years for the heater, the annualized cost of purchasing the heater would be $42. The cost of the Ardrox 405-V is $12.13 per gallon when purchased in small quantities. Assuming the cleaner is used at 50 percent dilution and that 24 gallons of cleaner would be required, the cost of the cleaner is $146 annually. No additional labor would be required for use of the Ardrox 405-V. Because the water-based cleaner is heated, the electricity cost for the pump and heater in the cleaning system would increase. IRTA estimates the cost at $85 per year.

Table 2-7 shows the annualized cost comparison for the cleaning after printing for Hino. The cost of the three options, the VOC solvent, the soy based cleaner and the water-based cleaner is comparable. The cost of using the soy based cleaner is about three percent higher than the cost of using the VOC solvent. The cost of using the water-based cleaner is about one percent lower than the cost of using the VOC solvent.

Table 2-7
Annualized Cost Comparison for Hino

	Current VOC Cleaner	Soy Based Cleaner	Water-based Cleaner
Capital Cost	-	-	$42
Cleaner Cost	$300	$216	$146
Labor Cost	$3,120	$3,315	$3,120
Electricity Cost	$10	$10	$85
Total Cost	$3,430	$3,541	$3,393

Quickdraw

Quickdraw is located in West Los Angeles, California. The company is a textile printer and most of the work involves printing on T-shirts. Quickdraw has three presses. A picture of one of the presses is shown in Figure 2-5.

Quickdraw removes ink from the screens during the printing process. The company, like many other screen printers, also removes the ink from the screens at the end of the printing process so the screens can be recycled. Quickdraw uses one VOC solvent for the in-process cleaning, a blend of terpenes and mineral spirits, and a second VOC solvent for the end of process cleaning, an aerosol screen opener. All of the cleaning is performed by hand with wipes. After the wipes are used, they are sent off-site to an industrial laundry.

Figure 2-5. Automated Press at Quickdraw

IRTA conducted preliminary testing of several alternatives for cleaning after the printing process. The operator decided that a soy based cleaner called Soy Gold 2000 performed best. An MSDS for this cleaner is shown in Appendix A. IRTA provided Quickdraw

with the soy cleaner and the operator used it for several months. He indicated that it performed well. The soy is oily and must be rinsed with water before the screen can be reused.

Quickdraw uses 14 gallons per year of the VOC solvent for cleaning the screens after printing. The cost of the cleaner is $11.40 per gallon. The annual cost of purchasing the cleaner is $160. The cost of the alternative, the soy based product, is $9 per gallon. Assuming the same amount of soy and the VOC solvent would be used, the annual cost of using the soy would amount to $126.

Quickdraw spends about four hours per day cleaning screens after printing. Assuming the company operates five days per week and 52 weeks per year and that Quickdraw's labor rate is $10 per hour, the annual labor cost is $10,400. Quickdraw estimates that an extra hour of labor a day would be required to rinse the screens after cleaning with the soy. The labor cost for cleaning after printing with the soy would amount to $13,000 per year.

For the in-process cleaning, Quickdraw uses an aerosol screen opening cleaner. The company uses about one can every two weeks and the cost of the cleaner is $7 per can.

On this basis, the cost of using the screen opener for in-process cleaning amounts to $182.

IRTA tested one alternative for in-process cleaning. The cleaner is a blend of 60 percent white oil, 30 percent acetone and 10 percent mineral spirits. An MSDS for the white oil, acetone and VM&P mineral spirits are shown in Appendix A. Although the operator did not like the odor, the blend did clean effectively. The cost of the white oil is $16.50 per gallon. The cost of acetone is $9 per gallon and the cost of the mineral spirits is $6 per gallon. Taking these prices into account, the cost of the blend amounts to $13.20 per gallon. One aerosol can generally contains between 12 ounces and one pound of product. Using this assumption, and using a density for the cleaner of about seven pounds per gallon, Quickdraw uses about three gallons of screen opener a year for in-process cleaning. Assuming the same amount of the alternative blend would be required, the cost of using the alternative in-process cleaner would amount to $40 annually.

Table 2-8 shows the annualized cost comparison for Quickdraw. The cost of using the alternative low-VOC cleaners is 23 percent higher than the cost of using the VOC cleaners.

Table 2-8
Annualized Cost Comparison for Quickdraw

	High VOC Cleaners	Soy and White Oil Cleaners
Cleaner Cost	$342	$166
Labor Cost	$10,400	$13,000
Total Cost	$10,742	$13,166

LCA Promotions Inc.

LCA Promotions is a textile printer located in Chatsworth, California. Much of the work involves printing on T-shirts but the company also prints on woven shirts, sweaters, activewear, headwear, outer wear and accessories like backpacks and aprons.

Until recently, LCA used lacquer thinner purchased from Home Depot for in-process cleaning during printing and after printing. During and after printing, the cleaner was applied by hand with wipes that are shipped off-site to an industrial laundry. The owner of LCA purchased a parts cleaner and is now using a different VOC cleaner. A picture of the new parts cleaner is shown in Figure 2-6.

IRTA performed preliminary screening tests with several alternative cleaners with the owner of LCA. Three cleaners worked well and left the emulsion intact. The first cleaner, an emulsion of water and mineral spirits, is called Hydroclean. IRTA provided LCA with a parts cleaner containing a concentration of Hydroclean of 12.5 percent. The cleaner was tested at the end of the printing process and it did not perform well.

Figure 2-6. Parts Cleaner at LCA Promotions

The second cleaner tested at LCA in the parts cleaner was Soy Gold 2000, a vegetable based cleaner. An MSDS for this cleaner is shown in Appendix A. LCA tested the soy cleaner for several weeks in the parts cleaner. IRTA also provided the facility with the

soy based cleaner so it could be tested for hand cleaning as well. The cleaner performed as well as their current cleaner. An extra step was required to rinse the soy.

The third cleaner tested at LCA was a water-based cleaner called Ardrox 405-V. An MSDS for this cleaner is shown in Appendix A. IRTA tested this cleaner in the parts cleaner at a 50 percent concentration. It was heated to about 105 degrees F and it performed well.

For the in-process cleaning, IRTA tested a blend of 60 percent white oil, 30 percent acetone and 10 percent mineral spirits. MSDSs for the white oil, the acetone and the VM&P mineral spirits are shown in Appendix A; like soy, the white oil has very low VOC content. The operator indicated that the lacquer thinner worked a little better but that the alternative did perform acceptably. The evaporation rate of the alternative in-process cleaner was judged by the operator to be just right.

IRTA analyzed and compared the cost of using the lacquer thinner, the new VOC cleaner and the alternative for cleaning during printing and the two alternatives for cleaning after printing. LCA used about 30 gallons per month or 360 gallons per year of the lacquer thinner. The owner estimates that 95 percent of the cleaner was used at the end of the cleaning process and five percent was used for in-process cleaning. On this basis, 342 gallons of the cleaner were used after printing and 18 gallons were used during printing

each year. The cost of the cleaner, which was purchased in one-gallon quantities at hardware stores, is $6 per gallon. The annual cost of purchasing the cleaner was $2,052 for cleaning after printing and $108 for in-process cleaning.
The new VOC cleaner is used in a parts cleaner with a 30 gallon capacity for cleaning after printing. LCA recently purchased a parts cleaner which is used with the new VOC cleaner. The cost of the parts cleaner was $1,500. Assuming a useful life for the parts cleaner of 10 years and a cost of capital of four percent, the annualized cost of the parts cleaner amounts to $156. IRTA estimates that the new VOC cleaner would require changeout every three months. LCA would also need 18 gallons of the cleaner each year for in-process cleaning. The cost of the cleaner is $10.50 per gallon. The cost of purchasing the cleaner for in-process and after printing cleaning is $1,449 annually. The unheated parts cleaner would use electricity for the pump and IRTA estimates this cost at $50 per year.

LCA workers spend eight hours per day cleaning. Assuming a five day week and 52 weeks per year and adopting LCA's labor rate of $8 per hour, the labor involved in cleaning activities amounts to $16,640 annually.

For the in-process cleaning, IRTA estimated the cost of the alternative based on the raw material cost of the components purchased in small quantities. The cost of the white oil is $16.50 per gallon. The cost of acetone is $9 per gallon and the cost of the mineral spirits is $6 per gallon. On this basis, the cost of the blend is $13.20 per gallon. Assuming LCA purchases 18 gallons for in-process cleaning, the annual cost of the cleaner would amount to $238. The labor would remain the same for the alternative in the in-process cleaning.

For cleaning after printing, it was assumed that the soy based cleaner would be used for hand cleaning in the same manner as the lacquer thinner. The cost of the soy is $9 per gallon. Assuming 342 gallons would be required, the annual cost of purchasing the soy for hand cleaning is $3,078. In this scenario, the labor would increase because the screens would require rinsing to remove the soy.

For cleaning after printing, IRTA also analyzed the cost of using the soy cleaner or the water-based cleaner in the parts cleaner. The water-based cleaner, to be effective, needs to be heated. If LCA purchased a heater for the parts cleaner, it would cost $400. Making the same assumptions as for the parts cleaner, the annualized cost for the heater would be $42. The parts cleaner with the added heater would use more electricity at a cost of $466 annually based on a usage rate of eight hours per day.

Based on the cleaning tests with the parts cleaner, the soy and the water-based cleaner would require changeout every three months. Assuming a capacity of 30 gallons for the parts cleaner and a cost of $9 per gallon for soy, the annual cost of soy for the parts cleaner would amount to $1,080 per year. The cost of the water-based cleaner is $7.50 per gallon for drum quantities and the cleaner is used at 50 percent concentration. On this basis, the annual cost of purchasing the water-based cleaner for the parts cleaner would be $450.

No additional labor would be required for using the water-based cleaner. Because the screens need to be rinsed after cleaning with the soy based cleaner, there would be an additional labor cost for the hand cleaning and for cleaning in the parts cleaner. The increased labor is estimated at one-half hour per day. On this basis, the increase in the labor cost would be $1,040 annually.

LCA pays $45 per week for sending the soiled rags to an industrial laundry and receiving fresh rags. The annual cost of this service amounts to $2,340. Use of the soy cleaner for hand cleaning would lead to the same cost. Use of the cleaners in the parts cleaner would require disposal every three months when the parts cleaner is changed out. For all three cleaners, disposal of two drums of waste per year would be required. The cost of disposal is estimated at $200 per drum for an annual cost of $400. Use of the parts cleaner would reduce the cost of the service for the rags. Assuming that five percent of the cleaning, the in-process cleaning, would still need to be done with rags, the cost of the rag service with the parts cleaner would be $117 annually.

Table 2-9 compares the cost of five scenarios. The first case is the use of lacquer thinner for hand cleaning. The second case is the case of the high VOC solvent used in the parts cleaner. The third case is the use of soy for hand cleaning. The fourth case is the use of soy in the parts cleaner. The fifth case is the use of the water-based cleaner in the parts cleaner. The cleaner used after printing is referred to as Cleaner A in the table and the in-process cleaner is called Cleaner B. The scenarios assume that the alternative in-process cleaner is used for the last three cases.

Table 2-9
Annualized Cost Comparison for LCA Promotions

	Lacquer Thinner Hand	VOC Solvent Parts Cleaner	Soy Hand	Soy Parts Cleaner	Water-Based Parts Cleaner
Capital Cost	-	$156	-	$156	$198
Cleaner A Cost	$2,052	$1,260	$3,078	$1,080	$450
Cleaner B Cost	$108	$189	$238	$238	$238
Labor Cost	$16,640	$16,640	$17,680	$17,680	$16,640
Electricity Cost	-	$50	-	$50	$466
Disposal Cost	$2,340	$517	$2,340	$517	$517
Total Cost	$21,140	$18,812	$23,336	$19,721	$18,509

The lowest cost option in Table 2-9 is use of the water-based cleaner in a parts cleaner. The cost of this option is about 12 percent lower than the baseline option of the lacquer thinner cleaning by hand. Using the VOC solvent in a parts cleaner is also lower cost than using the lacquer thinner for hand cleaning by about 11 percent. The cost of using the soy based cleaner in a parts cleaner is also lower in cost by seven percent than cleaning with the lacquer thinner by hand. Cleaning with the soy by hand is 10 percent higher in cost than cleaning with the lacquer thinner by hand.

Totally Ink

Totally Ink is a small textile screen printer located in Northridge, California. The company prints on T-shirts, hats, jackets and magnetic signs. A picture of a press at Totally Ink is shown in Figure 2-7.

Figure 2-7. Automated Press at Totally Ink

The practice at Totally Ink is to clean the screens by hand using wipe cloths. Historically, the company used mineral spirits for cleaning the screens. The mineral spirits is purchased from hardware stores and the company uses about one-fourth gallon of the solvent per week or 13 gallons per year. The cost of the solvent is $11 per gallon. On this basis, the annual cost of cleaning at Totally Ink is $143.

IRTA tested alternative low-VOC cleaners with Totally Ink as part of a project sponsored by the SCAQMD. IRTA provided one gallon each of four different cleaners to the facility over a period of several months. The alternative cleaners included three water-based cleaners, Ardrox 405-V, Mirachem NP 2520 and Metalnox M6521, and a soy based cleaner called Soy Gold 2500. MSDSs for all four cleaners are provided in Appendix A. The company tested each of the cleaners and found them all acceptable. The owner did indicate, however, that he liked the Mirachem NP 2520 and the Soy Gold 2500 the best.

The cost of the Ardrox 405-V is $12.13 per gallon when it is purchased in small quantities. The cost of the Mirachem cleaner is $12.50 per gallon. The cost of the Kyzen cleaner is $16.20 per gallon and the cost of the Soy Gold 2500 is $12 per gallon. The alternative cleaners are not likely to evaporate as quickly as the mineral spirits so less of these cleaners might be required. Assuming the same amount of the alternatives is required, the annual cost of using the Ardrox 405-V, the Mirachem, the Kyzen cleaner and the Soy Gold 2500 amounts to $158, $163, $211 and $156 respectively.

Table 2-10 shows the annualized cost comparison for the cleaning at Totally Ink. The mineral spirits, the high VOC cleaner used currently, is the lowest cost cleaner. The annual cost of using Soy Gold 2500 is nine percent higher than the annual cost of the mineral spirits. The annual cost of using the Ardrox, the Mirachem and the Kyzen is 10, 14 and 48 percent higher respectively than the cost of using the mineral spirits.

Table 2-10
Annualized Cost Comparison for Totally Ink

	Mineral Spirits	Ardrox 405-V	Mirachem NP2520	Kyzen M6521	Soy Gold 2500
Cleaner Cost	$143	$158	$163	$211	$156
Total Cost	$143	$158	$168	$211	$156

Applied Pressure, Inc.

Applied Pressure is located in Chatsworth, California. The company has provided screen printing services to the contract apparel industry since 1990. Applied Pressure has 25 employees and 90 percent of the business involves printing on T-shirts. The company has 14 automated screen printing presses and a few manual presses.

IRTA began working with Applied Pressure as part of a project sponsored by the South Coast Air Quality Management District. The purpose of the project is to identify, test and demonstrate low-VOC, low toxicity alternative screen cleaning formulations.

Applied Pressure cleans between 60 and 70 screens per day. The company leases a parts cleaner that relies on mineral spirits for cleaning the screens. IRTA performed screening tests of four different cleaners at the facility. During these tests, IRTA had an employee clean screens by hand with a wipe cloth. The employee was asked to judge which cleaner cleaned the best. IRTA provided the facility with a heated parts cleaner and four different cleaners were tested in the course of the testing program.

The first cleaner that was tested in the parts cleaner was a cleaner made by Kyzen. The cleaner was heated and the concentration of the cleaner was adjusted a few times. The facility employees did not think this cleaner cleaned the ink effectively. The second cleaner that was tested was a water-based cleaner called Ardrox 405-V. This cleaner performed more effectively but the employees indicated that it did not perform as well as the mineral spirits. The third cleaner that was tested was another water-based cleaner called Mirachem NP 2520. The employees liked this cleaner and it performed as well as the mineral spirits. The fourth cleaner that was tested was Soy Gold 2500. The employees did not like this cleaner even though it cleaned the ink effectively because it required rinsing. MSDSs for the four cleaners that were tested are provided in Appendix A.

Applied Pressure leases the mineral spirits parts cleaner from a service provider. The service provider provides the parts cleaner and fresh mineral spirits and changes out the mineral spirits and disposes of it as hazardous waste. The cost of this servicing arrangement is $500 per month or $6,000 per year.

The most successful alternative was the Mirachem NP 2520 and IRTA compared the current cost of using mineral spirits with using Mirachem. Two types of heated parts cleaner are available for water-based cleaners. The most common type of parts cleaner is made of plastic. The screen industry, because of the inks, is very hard on parts cleaners so IRTA analyzed both a plastic and a stainless steel parts cleaner which would probably be more durable. IRTA assumed the company would purchase the parts cleaner rather than lease it because this is generally a much lower cost option. The cost of a plastic parts cleaner is $1,675 and the cost of the stainless steel parts cleaner is $3,800. The parts cleaners should last for 10 years. Because Applied Pressure would use the parts cleaner so heavily, it is likely that four heaters and two pumps would require replacement over the period. A pump could be replaced for $105 and a heater for $90 including parts and labor. The total cost of replacement parts and labor would be $570. The total capital cost for the plastic parts cleaner including the replacement is $2,245. The total capital cost for the stainless steel parts cleaner including the replacement is $4,370. Assuming a cost of capital of four percent, the annualized cost for the plastic parts cleaner and stainless steel parts cleaner is $233 and $454 respectively.

During the testing, the parts cleaner containing the Mirachem cleaner was changed out in six weeks. It was not spent and it could have been used longer. IRTA examined two scenarios, one a six week servicing and the other an eight week servicing. The Mirachem supplier estimated that the company would service the parts cleaner every six weeks at a cost of $282 per servicing and every eight weeks at a cost of $297. The servicing would include cleaning out the parts cleaner, disposing of the spent cleaner as hazardous waste and replenishing the parts cleaner with new Mirachem NP 2520. The annual cost of the servicing every six weeks is $2,444 and the annual cost of the servicing every eight weeks is $1,931.

The mineral spirits parts cleaner has a one-fourth horsepower pump which runs perhaps four hours per day. Over a one-year period, the electricity cost would be $42. The water-based parts cleaner has the same pump but also includes a small two kW heater. The heater maintains the temperature at about 105 degrees F and runs much less frequently than the pump. Assuming the parts cleaner is used for four hours per day, that it cycles on half the time, that it is used 260 days per year and that the electricity cost is

12 cents per kWh, the annual electricity cost for the water-based parts cleaner is estimated at $167.

Table 2-11 shows the cost scenario for Applied Pressure assuming a six week changeout of the water-based cleaner. The figures show that the cost of using the plastic parts cleaner with the water-based cleaner is less than half the cost of using the mineral spirits. The cost of using the stainless steel parts cleaner is about half the cost of using the mineral spirits.

Table 2-11
Annualized Cost Comparison for Applied Pressure (Six Week Changeout)

	Mineral Spirits	Water-Based Cleaner	
		Plastic Parts Cleaner	Stainless Steel Parts Cleaner
Annualized Capital Cost	-	$233	$454
Electricity Cost	$42	$167	$167
Servicing Cost	$6,000	$2,444	$2,444
Total Cost	$6,042	$2,844	$3,065

Table 2-12 shows the cost scenario for Applied Pressure assuming an eight week changeout of the water-based cleaner. The cost of using the plastic parts cleaner, in this case, is 61 percent lower than the cost of using the mineral spirits. The cost of using the stainless steel parts cleaner is 58 percent lower than the cost of using the mineral spirits.

Table 2-12
Annualized Cost Comparison for Applied Pressure (Eight Week Changeout)

	Mineral Spirits	Water-Based Cleaner	
		Plastic Parts Cleaner	Stainless Steel Parts Cleaner
Annualized Capital Cost	-	$233	$454
Electricity Cost	$42	$167	$167
Servicing Cost	$6,000	$1,931	$1,931
Total Cost	$6,042	$2,331	$2,552

<u>Powerhouse Screen Printing, Inc.</u>

Powerhouse is located in Santa Ana, California. The company provides screen printing services to the contract apparel industry and the production manager has 23 years of experience in the industry. The company has four employees and most of the business is printing on T-shirts. Powerhouse has a 14 color automated press; a picture of this press is shown in Figure 2-8.

Figure 2-8. Automated Press at Powerhouse

IRTA began working with Powerhouse as part of a project sponsored by the South Coast Air Quality Management District. The purpose of the project is to identify, test and demonstrate low-VOC, low toxicity alternative screen cleaning formulations.

The company leased a parts cleaner that relies on mineral spirits for cleaning the screens. IRTA performed initial testing on the company's ink and identified four alternative cleaners that seemed to clean the ink well. They included three water-based cleaners--Mirachem NP 2520, a cleaner made by Kyzen, a cleaner called Ardrox 405-V--and a soy based cleaner called Soy Gold 2500. MSDSs for the four cleaners are shown in Appendix A. IRTA provided one gallon of each of these cleaners to the company. After testing, the company decided that Soy Gold 2500 performed the best, followed by the Mirachem NP 2520.

For scaled-up testing, IRTA provided the company with a parts cleaner and the Soy Gold 2500. The soy based product cleaned the ink very effectively but it also dissolved the adhesive used to bond the screen material to the wood. IRTA then provided the company with the Mirachem NP 2520 which was tested in the parts cleaner for several weeks. According to the shop personnel, the cleaner performed very well and Powerhouse has converted to the alternative.

When the company used mineral spirits, the service provider leased the parts cleaner to Powerhouse, changed out the cleaner every 12 weeks and disposed of the spent cleaner as hazardous waste. The cost of each 12 week servicing was $430. On an annual basis, the total cost amounted to $1,863.

Powerhouse decided to purchase the used plastic parts cleaner they had used in the alternatives testing. The cost of the parts cleaner was $850. Assuming a four percent cost of capital and a ten year life for the equipment, the annualized cost of the parts cleaner is $88.

The cost of the Mirachem NP 2520 is $552 for a 55 gallon drum. This is a cost of $10.04 per gallon. The supplier does not charge a delivery fee if the customer allows a few weeks for delivery. During the alternatives testing, the shop personnel indicated that the water-based cleaner might last longer than the mineral spirits. IRTA analyzed two scenarios for the alternatives, one a 12 week changeout cycle and one an eighteen week changeout cycle. For each changeout cycle, 15 gallons of the Mirachem NP 2520 would be required to achieve a 50 percent concentration in the parts cleaner. The cost of the cleaner for the 12 week changeout cycle is $653 per year. For the 18 week changeout cycle, the cost of the cleaner amounts to $435 per year.

The cost of servicing the parts cleaner would involve disposing of the spent cleaner and recharging the parts cleaner with fresh cleaner. The cost of this servicing is $158 per service. For the 12 week service cycle, the servicing cost would amount to $685 per year. For the 18 week service cycle, the servicing cost would be $456.

The mineral spirits parts cleaner had a one-fourth horsepower pump which ran perhaps two hours per day. Over a one year period, the electricity cost would be $21. The water-based parts cleaner has the same pump but also includes a small two kW heater. The heater maintains the temperature at about 105 degrees F and runs much less frequently than the pump. Assuming the parts cleaner is used for two hours per day, that it cycles on half the time, that it is used 260 days per year and that the electricity cost is 12 cents per kWh, the annual electricity cost for the water-based cleaner is estimated at $83.

Table 2-13 shows the cost scenario for Powerhouse assuming a 12 week changeout cycle. The cost of using the water-based cleaner is 20 percent lower than the cost of using the mineral spirits.

Table 2-13
Annualized Cost Comparison for Powerhouse (Twelve Week Changeout)

	Mineral Spirits	Water-Based Cleaner
Annualized Capital Cost	-	$88
Servicing Cost	$1,863	$685
Cleaner Cost	-	$653
Electricity Cost	$21	$83
Total Cost	$1,884	$1,509

Table 2-14 shows the cost comparison assuming the water-based cleaner has an 18 week changeout cycle. The cost of using the water-based cleaner, in this case, is 44 percent lower than the cost of using the mineral spirits.

Table 2-14
Annualized Cost Comparison for Powerhouse (Eighteen Week Changeout)

	Mineral Spirits	Water-Based Cleaner
Annualized Capital Cost	-	$88
Servicing Cost	$1,863	$456
Cleaner Cost	-	$435
Electricity Cost	$21	$83
Total Cost	$1,884	$1,062

A case study for Powerhouse is presented in Appendix B.

Other Facilities

In the earlier project IRTA conducted with SCAQMD, alternatives were tested with three facilities that are worth mention here. The detailed analysis and results of the testing are available in "Assessment, Development and Demonstration of Low-VOC Cleaning Systems for South Coast Air Quality Management District Rule 1171," August 2003. The first facility, Teledyne Microelectronic Technologies, prints with conductive and dielectric ink on ceramic substrates. The second facility, City of Santa Monica Paint Shop, prints on various types of substrates including paper, metal and plastic. For both facilities, IRTA identified an effective alternative cleaner, acetone, that met the 100 gram per liter VOC limit. The third facility, Nelson Nameplate, prints on metal and plastic substrates and removes ink from the screens during printing and during recycling. IRTA identified an alternative cleaner, composed of 92 percent acetone and eight percent propylene glycol ether, that met the 100 gram per liter VOC limit. This cleaner can be used to remove ink from the screens during printing and during recycling. Nelson staff indicated that more of the cleaner was required for cleaning and the cleaner gave inconsistent results, dried too quickly and irritated the skin of some workers. The company wanted to continue testing to see if improvements could be made. IRTA conducted substantial additional testing of cleaners with a VOC content of 200 grams per liter. Although some of the cleaners cleaned the ink effectively, IRTA ended the testing without finding a cleaner that was acceptable to Nelson.

III. PROJECT RESULTS AND CONCLUSIONS

During this project, IRTA staff worked with twelve screen printers to test alternative safer, low-VOC cleanup materials. SCAQMD Rule 1171 currently allows screen printers to use cleaners with 500 grams per liter VOC; in July, 2006, the VOC level will decline to 100 grams per liter.

IRTA staff tested alternatives with the twelve participating facilities for in-process cleaning and screen recycling. All of the alternatives that were tested had a VOC content of 100 grams per liter or less. The alternatives that were tested fall into three categories including water-based cleaners, soy based cleaners and exempt solvent blends. In general, these alternatives are lower in toxicity than the higher VOC cleaners used by the industry.

Table 3-1 summarizes the alternatives that were tested successfully at each of the facilities that participated in the project. The table also specifies the type of ink used by each facility.

Table 3-1
Successful Safer and Low-VOC Alternatives

Company	Ink Type	Successful Alternative(s)
Owens-Illinois	UV	Soy Based Cleaner
Southern California Screen Printing	UV	Water-Based Cleaner, Soy Based Cleaner
Com-Graf	Solventborne	Soy/Acetone/Mineral Spirits Blend
Serendipity	Solvent and waterborne	Acetone/Mineral Spirits Blend
Oberthur	Solvent and waterborne	Acetone/EEP Blend
Texollini	Waterborne	Water-Based Cleaner
Hino Designs	Plastisol	Water-Based Cleaner, Soy Based Cleaner
Quickdraw	Plastisol	Soy Based Cleaner, White Oil/ Acetone/Mineral Spirits Blend
LCA Promotions	Plastisol	Soy Based Cleaner, Water-Based Cleaner, White Oil/Acetone/ Mineral Spirits Blend
Totally Ink	Plastisol	Water-Based Cleaners; Soy Based Cleaner
Applied Pressure	Plastisol	Water-Based Cleaners
Powerhouse	Plastisol	Water-Based Cleaner

Table 3-1 indicates that UV curable ink can be cleaned with soy and water-based cleaners at Owens-Illinois and Southern California Screen Printing. Com-Graf, Serendipity and Oberthur can clean their solventborne ink with acetone blends. The cured waterborne ink at Texollini was cleaned successfully with a water-based cleaner. The six textile printers, Hino Designs, Quickdraw, LCA Promotions, Totally Ink, Applied Pressure and Powerhouse, cleaned their plastisol ink successfully with water-based cleaners and soy based cleaners during screen recycling. For in-process cleaning, the textile printers can clean with a white oil/acetone blend.

The cost analysis indicates that the alternatives are lower cost in some cases and higher cost in other cases. Owens-Illinois converted to the soy based cleaner and reduced their cost. Southern California Screen Printing would increase their cost if they converted to the soy based cleaner; their cost would remain about the same if they converted to the water-based cleaner. Com-Graf and Oberthur would both reduce their cost by converting to the alternative acetone blends. Serendipity would increase their cost by converting to the acetone blend. Texollini converted to the water-based cleaner alternative and reduced their cost substantially in the process. The cost at Hino Designs would remain about the same if the company converted to the soy based or water-based alternative. Quickdraw would increase their cost by converting to the alternatives. LCA Promotions would reduce their cost by converting to the water-based cleaner but would increase their cost by converting to the soy based cleaner. Totally Ink would increase their cost by converting to the soy or water-based cleaners. Both Applied Pressure and Powerhouse would reduce their cost by converting to the water-based cleaners.

The results of the project indicate that screen printers using a variety of different ink types and printing on different substrates can find safer alternatives. The alternatives tested here were generally lower in toxicity than the cleaners used by the facilities today. The alternatives were also low in VOC content; all the alternative cleaners that were tested had a VOC content of 100 grams per liter or less. In some cases, use of the alternatives would increase costs but in most cases, the cost of using the alternative would be less or about the same.