J. ENVIRON. SCI. HEALTH, A36(10), 1957–1973 (2001)

SOLVENT EXPOSURES IN SCREEN PRINTING SHOPS

Sanford W. Horstman,[1,*] Steven R. Browning,[1]
RaeAnne Szeluga,[1] Jennifer Burzycki,[2] and Arlene Stebbins[3]

[1]Department of Preventive Medicine and Environmental Health, University of Kentucky, Chandler Medical Center, 1141 Red Mile Rd, Lexington, KY 40504
[2]Boeing Commercial Airplane Company, P.O. Box 3707, T-1870 001/01, Seattle, WA 98124-2207
[3]Department of Labor and Industries, P.O. Box 44610, Olympia, WA 98504-4610

ABSTRACT

A comprehensive description of working conditions, exposure patterns for organic solvents, and related health symptoms among workers in ten small screen printing companies located in Seattle, Washington, is presented. Sampling methods included continuous area monitoring, grab sampling, personal sampling, and time study observation. A total of 27 workers were observed and monitored for solvent exposure. Short-term peak exposures were characterized in terms of magnitude, duration and repetition, and their contribution to time weighted average (TWA) exposures were evaluated. A health questionnaire addressing the symptoms potentially attributable to solvents was used to investigate the possible health effects from exposure. Significant differences in the prevalence of headaches, dizziness, intoxication, and dry skin ($p < 0.01$) were reported among workers who had some solvent exposure compared with the referent group that was not exposed. Exposed workers were also more likely to report fatigue, loss of strength in the arms and hands, difficulty concentrating, sore throat, and a low alcohol tolerance.

*Corresponding author. E-mail: swhors1@pop.uky.edu

The study documented highly variable levels of solvent exposures. Screen printing workers in different companies, while performing the same basic tasks, had time weighted average (TWA) exposures ranging from 2% to 100% of the recommended threshold limit value (TLV) for mixtures. Continuous monitoring indicated that high short-term exposures are responsible for the bulk of TWA exposures. Grab samples and continuous monitoring verified that recommended Short Term Exposure Limits (STEL) for individual solvents may be exceeded on a routine basis. Frequent skin contact with solvents was also observed. Health problems in this industry and other small industries using organic solvents may result from these complex patterns of exposure.

Key Words: Graphic arts; Solvent exposures; Screen printing; Small industry

INTRODUCTION

Smaller companies have been understudied with respect to chemical exposure and exposure patterns (1–3). When compared with larger companies, companies with less than 30 employees frequently have higher peak exposure levels and a more variable chemical exposure pattern than larger companies in the same industry (1, 2). In a study of auto body repair companies with few employees, a pattern of high peak exposures to mixed solvent was reported, with time weighted average levels (TWA) below the mixed solvent exposure threshold limit values (TLV) (4). Workers in these companies had extensive skin contact with solvents. A subsequent analysis of biomonitoring data confirmed the importance of skin absorption as a significant route of exposure (5). These observations are applicable to the many small industries where employees perform multiple tasks using a variety of organic solvents. Small industries such as printing, graphic arts, dry cleaning, auto body repair, and marine repair make frequent use of solvents and often lack engineering controls and personal protective equipment for their employees. If personal protection is used in these industries, it is often inappropriate and inadequate (1–5).

In March 1982, the National Institute of Occupational Safety and Health (NIOSH) conducted a study of five small screen printing shops in response to health complaints (6). The investigation included personal and area samples, work diary reports, urine sampling for solvent metabolites, symptom questionnaires, and neurobehavioral tests. The results were statistically inconclusive regarding medical and behavioral effects. Average personal exposures for all solvents were well below the exposure criteria, although task sampling identified processes with high peak exposures. By combining task information from work diaries with short-term exposure measurements for the tasks, an estimate of the worker's TWA exposure was constructed. For a group of seven workers, the estimate using this method was found to closely approximate the exposure determined with personal charcoal tube sampling (6).

In a study of 52 male offset printers (non-screen printing), Baelum and colleagues found an excess of health complaints and neurological symptoms at cumulative solvent levels far below the regulatory limits. The primary complaints were irritation of eyes, nose and throat, disorders of vision, vertigo, intoxication, and headaches (7). Similar results were reported in a study of 41 female silk screen printers (serigraphy) in Denmark (8). Thirty-nine of the 41 printers were referred for medical evaluation because of potential nervous system effects. At clinical examination, 15 workers had signs of chronic solvent intoxication and 13 had signs of acute solvent intoxication. Of the workers examined, symptoms resolved following removal from exposure within six months, except for one worker suspected of having minor chronic nerve damage; the plant had a working ventilation exhaust system. The solvents used contained cyclohexanone, xylene, and toluene. Results of breathing zone sampling over a period of six years had shown air levels ranging from 30% to 80% of the Danish TLV for solvent mixtures.

Several occupational studies have documented neuropsychological deficits in workers with acute and chronic exposures to mixed solvents even when the air concentrations of the solvents are within occupational standards (9, 10). Ng et al. reported on solvent-exposed workers from 11 Singapore factories with screen-printing and paint spraying processes (9). The mean mixed solvent exposure for the exposed group of workers was 0.39 of the threshold limit value, as assessed by the additive formula for mixed exposures from the ACGIH. They estimated that 9% of the measurements exceeded the threshold limit value. After adjustment for age and education, the exposed group had significantly more symptoms of fatigue and irritability and more complaints of short-term memory loss. White and colleagues found that persons categorized as having higher acute solvent exposures, although all levels were below the recommended TLV, demonstrated significantly impaired test performance on tasks involving manual dexterity, visual memory, and mood (10).

The present study was undertaken in response to several complaints from workers in small screen printing shops in Seattle, Washington. This study was undertaken as a comprehensive characterization of exposures to solvents and associated health symptoms among employees working in small screen printing companies. Secondary objectives of the investigation were to characterize the tasks associated with the highest solvent exposures, to assess whether the grab sampling approach accurately characterizes the work environment, and to determine the range of exposure variability between well-ventilated and poorly ventilated shops.

Screen Printing Process Description

Small commercial screen printing companies deal primarily in advertising graphics, such as road and real estate signs, billboards, posters, decals, banners, and awnings. This research specifically focused on flat poster-type screen printing. The industry has been developing commercially in the United States for about forty years. The screen printing process was originally designed to replace the time-consuming task of hand painting signs and other graphic art displays and facilitate the production of multiple copies of these graphic displays.

The screen printing process follows a sequential procedure. First, mesh fabric is stretched tightly on a frame. Areas of the screen are then blocked out by the use of photo-exposed stencils and an alcohol-based liquid, leaving the image of the print open. The frame is "set-up" on a table with hinges at the back so it can be raised to place a blank poster board or other stock under the screen. Ink is then squeezed through the open areas of the mesh with a "squeegee," which produces an even coat of ink on the blank product placed under the screen. The process is repeated for a number of prints. Finished products are laid on a rack or conveyor-type dryer. Additional colors may be added when the ink is dry.

During screen printing, solvents (such as thinners and retarders) are used to modify flow penetration or drying rate of the ink. While prints are drying, ink solvents may be released into the shop atmosphere; however, the major exposures in this industry occur when workers clean the screens and equipment. Organic solvents are used to clean in two ways: during a printing run to clean out a screen clogged with dry ink or dust, and at the end of a run when washing the screen and associated equipment to prepare them for reuse.

Typically, the faster evaporating ketones and aromatics are used in all portions of the process. Most commonly used are the many formulations collectively known as "Lacquer Thinner," which consists of aromatics (toluene, xylene) and ketones (methyl ethyl ketone (MEK), acetone) with smaller fractions of alcohols (methanol) and glycol ethers (cellulose). Many of these have similar toxic (especially neurologic) effects, and the combined health effects of several solvents in a mixture are an important consideration (11). A printing run can vary from two prints to several thousand prints. Thus the number of screens used varies a great deal, especially if a shop specializes in small orders for advertising products.

Depending on the size of the screen (anywhere from 1–2 square feet to 50–60 square feet), a varying amount of solvent, from several ounces to several quarts, is used for wash-up. With a very large screen, it may take half an hour or more to clean the ink out of the mesh and corners of the frame. Increased solvent exposures are experienced through inhalation or dermal contact during the screen clean-up because of the close contact with the solvent.

In screen printing, the potential for absorption by both the respiratory and dermal routes of exposure appears to be substantial. Ventilation control measures at the point of printing are difficult to implement because adequate ventilation of a work station would cause drying of ink in the screen, affecting print quality and process efficiency. If ventilation is increased, the printer must clean dried ink from the screen more frequently.

METHODS AND MATERIALS

The primary purpose of the study was to provide a comprehensive description of working conditions, exposure patterns for organic solvents, and the related health symptoms in workers from a sample of small screen printing companies. The Field Research and Consultation Group, Department of Environmental Health, University of Washington performed the study from January through March 1988. An introductory letter was sent to approximately 100 screen printing companies in the Seattle and Tacoma areas. From this group, ten shops were selected which met the following criteria: less than ten (but preferably at least three) production workers and a primary emphasis on flat-work printing (posters, decals, signs, etc.) rather than textile or bottle printing. A physical inventory of all solvent-based chemicals in each workplace was obtained in order to discover potential exposures. The composition of each solvent was listed for all products for which a Material Safety Data Sheet was available.

Personal (6–8 h) time weighted average (TWA) air samples for solvent vapors were collected using charcoal badge dosimeters. These were attached in the breathing zone of one to three workers engaged for some fraction of time in the screen printing process or in cleaning screen printing equipment with organic solvents at each shop. Workers having the highest degree of contact with organic solvents were selected for monitoring by the investigators and company management. The management did not exclude any employees from the study but frequently suggested employees who had the most contact with solvents.

Analysis of TWA charcoal dosimeters was performed by an American Industrial Hygiene Association (AIHA) accredited laboratory, following the NIOSH method CAM 1500/1501, using gas chromatography (11). Spiked samples were submitted to the lab with each sample batch, and precision was determined by collecting two dosimeter badges simultaneously for one individual in each shop.

The charcoal dosimeter badges were analyzed for the following solvents: methyl alcohol, acetone, isopropyl alcohol, methyl ethyl ketone (MEK), methyl isobutyl ketone, toluene, xylene, glycol ether, and *n*-hexane.

All airborne computations are based on the Threshold Limit Value (TLVs), as published by ACGIH (12).

Grab sampling for organic solvents was performed with Drager direct reading detector tubes. There were four purposes for grab sampling with detector tubes. First, the sampling was used to verify and identify solvent classes (i.e. ketones, aromatics and alcohols) present in the shop atmosphere. Second, grab sampling was used to measure approximate air solvent concentrations during two-to-three-minute periods of peak exposure, such as occurs during cleaning of screens or equipment with lacquer thinner or printing with some quick drying inks. Third, the results from the grab samples served to confirm total hydrocarbon levels measured by continuous monitoring. Fourth, the results of grab sampling were compared to continuous total hydrocarbon monitoring results for three shops to validate the use of the grab sampling technique at the other facilities.

Real time monitoring was used to characterize patterns (i.e., magnitude, duration, and frequency) of peak atmospheric exposures. The instrument used for these measurements was an Analytical Instrument Development (AID) Total Hydrocarbon Analyzer Model 710, which incorporates a flame ionization detector (13). The output signal was recorded with a strip chart recorder and a digital data logger connected in series and set to average the output signal at five-second intervals. The instrument was moved to different locations within the shop in order to monitor selected areas and processes for a period of one to three hours.

Time study analysis was performed to describe the patterns of exposure (frequency and duration of certain activities) and to interpret badge-sampling results with respect to the percent of time spent in high exposure activities. Time study was performed for each employee wearing a charcoal dosimeter badge. At five-minute intervals, work activities were documented along with the materials employed, the use of personal protective equipment, and the potential for dermal absorption of solvents. Upon examination of the screen printing process, it was determined that exposure to organic solvents occurs primarily during printing and wash-up activities. Work activities were classified as "wash," "print," and "other."

A questionnaire to document medical history, occupational history, and symptoms associated with acute and chronic exposures to organic solvents was administered to all monitored workers, as well as to other production workers in the same areas. For comparison, non-production employees in each company were also asked to complete the form. Questions regarding alcohol, tobacco and caffeine use, as well as age, gender, and education, were included in order to assess differences in these variables between the exposed printers and the non-exposed employees (control group). Analysis of the questionnaire data was performed using a two-sample test for binomial proportions between exposed and non-exposed workers for responses to questions regarding nervous system and general symptoms.

RESULTS

The total number of workers in each shop and the number of workers monitored are given in Table 1. Two to three workers in each of the ten shops wore charcoal dosimeter badges for one or two full work shifts. A total of 45 samples were collected, representing one to two days of exposure for 27 production workers.

The arithmetic mean mixture exposure was 32% of the TLV, with a geometric mean of 22% and geometric standard deviation of 2.4 (12). TWA badge sampling results were highly variable both within and between shops, ranging from 5% to 100% of the mixture TLV (Figure 1).

Solvents found only in inks accounted for a small fraction of the mixed time weighted average (TWA), indicating that the majority of solvents represented were those used during wash-up. Depending on the shop, from 85% to 100% of the TWA badge results can be attributed to wash-up solvents, primarily toluene with a smaller fraction of xylene, and the remainder to ink solvents. The influence of toluene and xylene levels on the calculated percent of the mixture TLV is given in Figure 2.

Forty-five time study records corresponding to the 45 badge samples were collected concurrently. For individuals wearing dosimeter badges, the range of time spent washing screens varied from none to 21% of the work day, which indicates that time spent in high-exposure activity is highly variable in this industry. Ten of the monitored workers were not involved in printing when the survey was conducted. These individuals were either printers who did not have a printing job on the day sampled, or workers who support printing activities by racking printed work, making screens, cleaning screens, and housekeeping.

Table 1. Total Number of Workers Monitored at Ten Screen Printing Facilities

Shop ID Number	Number of Workers	Number of Workers Monitored
1	2	2
2	2	2
3	4	3
4	2	2
5	5	3
6	6	3
7	4	3
8	4	3
9	5	3
10	4	3
Total Number of Workers	38	27

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

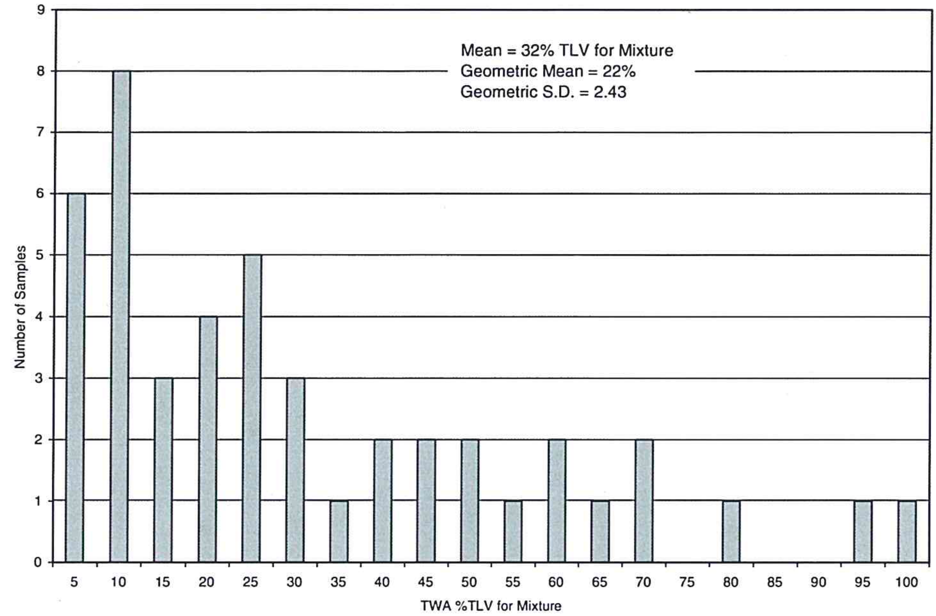


Figure 1. TWA exposure to mixed solvents.

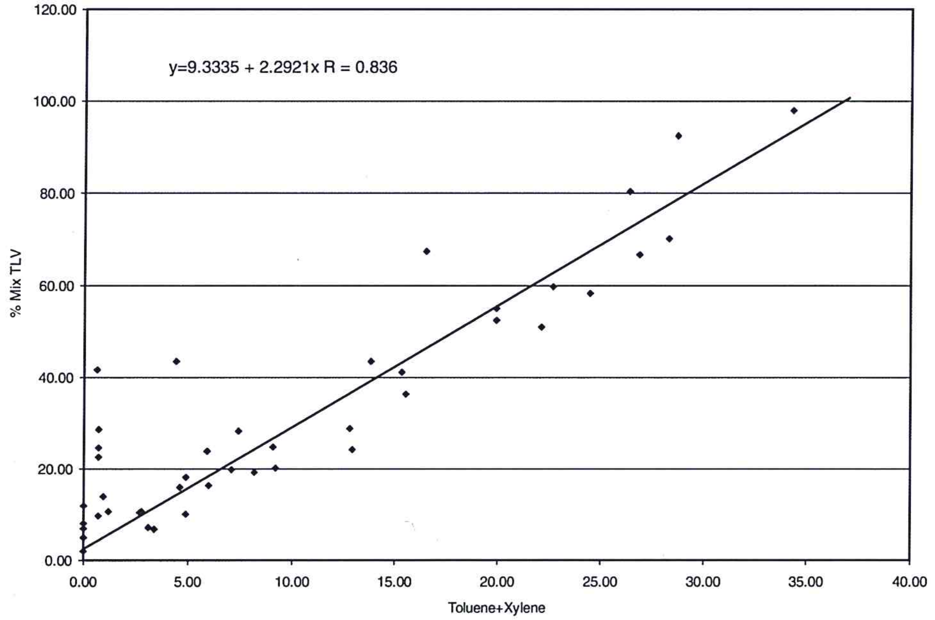


Figure 2. Regression analysis for the influence of toluene and xylene on the mixture TLV.

The distribution of time spent printing and washing for individual samples is given in Figure 3. The average time spent printing by workers wearing badges was 22% of the work day. Printing activity was also highly variable, ranging from none to 70% of the worker's time. The average time spent in these two activities combined was 29% of the work day. Printing and washing are integral activities, i.e. washing almost always occurs during or immediately after a printing job.

Five-minute average total hydrocarbon exposures, derived from continuously monitoring results for a period of one hundred minutes for a poorly ventilated shop, are given in Figure 4. Five-minute average concentrations were developed from the raw data, which was recorded at five-second intervals. In this poorly-ventilated shop, one five-minute period had an average of over 1100 ppm. The short-term exposure represented by minutes 50 through 65 represents fifteen minutes at an average of over 700 ppm total hydrocarbons. During the entire 100-min period the average solvent level was 280 ppm total hydrocarbons. Despite this high short term exposure level, the highest badge result in this shop was 64% of the mixed solvent TLV, or about 70 ppm averaged over the entire day. This shop was the most poorly ventilated of all the shops studied. Several partially open windows provided the only ventilation.

Figure 5 shows a similar period of one hundred minutes in a well-ventilated shop (mechanically induced general ventilation). It was evident that high

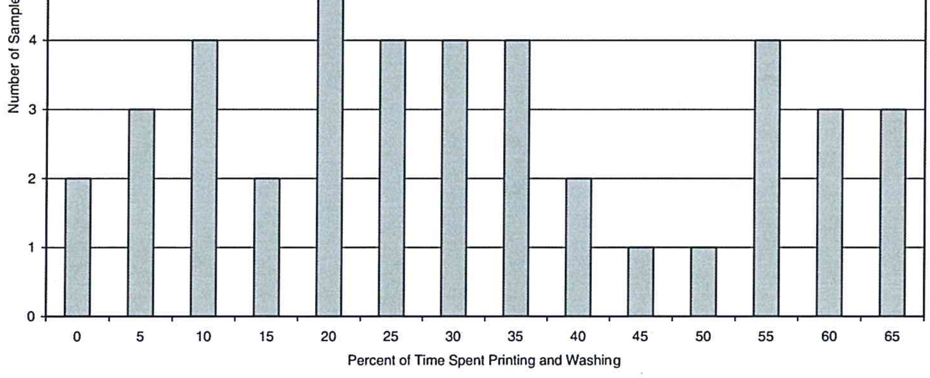


Figure 3. Distribution of time spent printing and washing by number of samples.

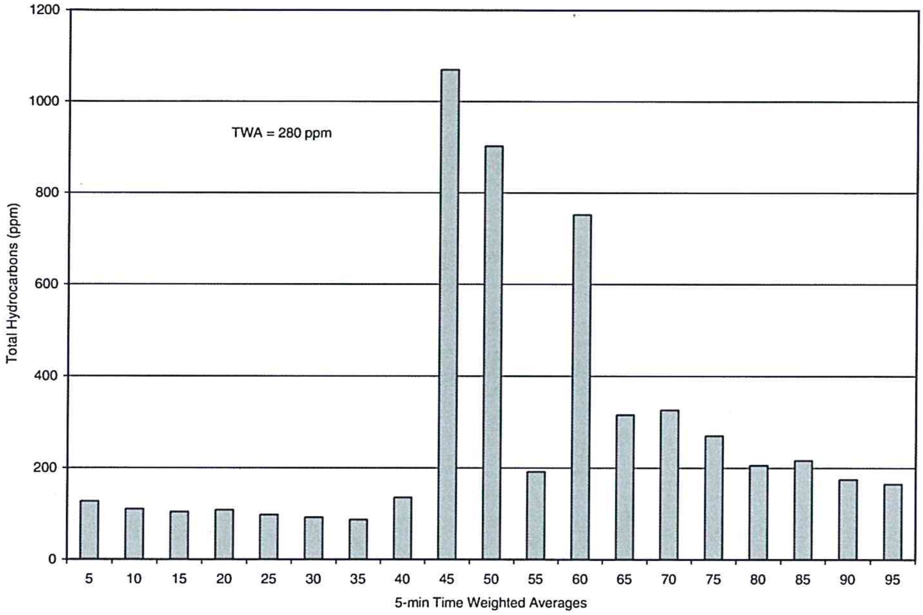


Figure 4. Distribution of 5-min average total hydrocarbon levels for a poorly ventilated shop.

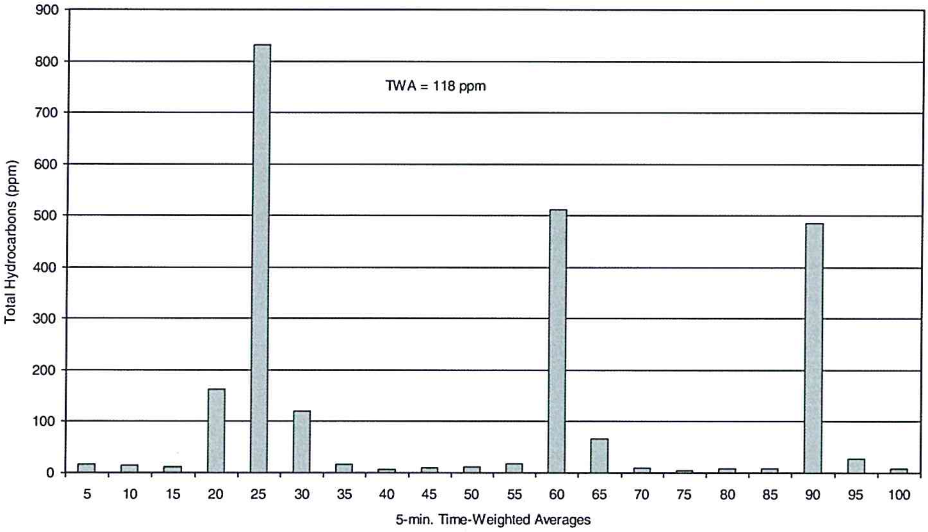


Figure 5. Distribution of 5-min average total hydrocarbon levels for a well ventilated shop.

peak levels are quickly controlled in this workplace. Rapid decay after washing events and the low ambient concentration demonstrate this control. The highest badge result in this shop was 37% of the mixed solvent TLV.

Table 2 compares grab samples with continuous monitoring by use of the flame ionization detector. The highest grab sample value measured for each class of solvent is tabulated for the three shops where continuous monitoring was also performed. Since the grab samples do not represent all of the solvents in the lacquer thinner mixture, the sum of the grab samples is adjusted by the fraction represented. This adjusted sum is compared with the range of continuous monitoring levels measured during the same or similar events. The sum of grab samples roughly agrees with total hydrocarbon levels obtained by continuous monitoring.

Time study observations during an 8-h workday were used to link specific activities with the measured time weighted average levels. The relationship between TWA exposures and time spent in high-exposure activities is shown in Table 3 for the 10 shops. The correlation coefficients express the relationship between the TWA for toluene versus the percent of time spent printing and washing, and for number of screen washing events. Workers spent from zero to seventy percent of the time washing and printing, and the corresponding TWAs for toluene ranged from 2 to 34 ppm.

A total of 70 health questionnaires were administered to workers. By directly observing the workers, forty-seven workers were classified as having frequent or occasional exposure to solvents. The remaining 23 workers were selected from office or management staff. There were no differences in caffeine, alcohol, and smoking between the two groups. The mean age of the non-exposed control group was several years older, the percentage of females was higher, and a greater percentage of the non-exposed group had some higher education (Table 4).

Responses to the health symptom questionnaire are given in Table 5. The exposed group had twice as many positive responses to questions about health symptoms than the non-exposed group. Significant differences ($p \leq 0.05$) between the exposed and control group were demonstrated for the following symptoms: lightheaded or dizziness, tire more easily, loss of strength in arms or hands, headaches more than once per week, difficulty concentrating at work, headaches at work, low alcohol tolerance, dry skin, and sore throat. The only symptoms reported by the non-exposed group at a higher rate (when compared to the exposed group) were hoarse throats and having to make notes in order to remember things.

DISCUSSION

When exposure concentrations of mixed organic solvents exhibit high variability, such as in the instance of small industry screen printing shops, the

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

Table 2. Comparison of Sampling Results for Detector Tubes vs. Continuous Monitoring During Wash-up Activity for Three Shops

Shop ID	Grab Samples, Highest Value by Detector Tube, by Class of Solvent (ppm)			Sum of Grab Samples (ppm)	Fraction of Wash-up Solvent Sampled with Detector Tubes	Total Hydrocarbon Calculated (Sum Grabs Divided by Fraction Sampled) (ppm)	Range for Continuous Monitoring Total Hydrocarbon Observed with Flame Ionization Detector (ppm)
	Ketone	Aromatic	Alcohol				
1	1000	200	–	1200	0.90	1300	500–1800
4	800	150	150	1100	0.80	1400	1200+
10	400	200	–	600	0.60	1000	900–2000

Table 3. Correlation Coefficients for Relationship Between Toluene Exposure and Time Study Data

Shop ID	Toluene TWA vs. Time Spent Printing and Washing	Toluene TWA vs. Number of Washing Events
1	0.78	0.99
2*	–	–
3*	–	–
4	0.65	0.78
5†	–	–
6	0.81	0.94
7	0.68	0.56
8*	–	–
9	0.95	0.69
10†	0.78	–

*Did not use toluene.
†Insufficient data obtained.

Table 4. Demographic and Health Characteristics of Workers in Ten Screen Printing Shops by Level of Solvent Exposure

	Occasional Exposure to Frequent Solvents ($n=47$) N (%)	No Exposure to Solvents ($n=23$) N (%)
Caffeine use	40 (85)	20 (87)
Alcohol use	31 (66)	15 (65)
Smoking	16 (34)	9 (39)
Male	31 (66)	10 (43)
Female	16 (34)	13 (57)
Education:		
Some high school	3 (6)	2 (9)
High school grad.	24 (51)	10 (43)
College	20 (43)	11 (48)

eight-hour TWAs measured by one or two days of sampling will not adequately characterize the exposure levels experienced by the workers. Exposure variability is one consequence of intermittent solvent use. Consequently, even if the daily average solvent exposure is less than the occupational exposure limit, high short-term exposures can and will occur during the work shift. The failure to characterize the factors associated with these peak exposures has implications for potential health effects that may result from elevated short-term exposure, which occurs during tasks such as screen cleaning.

Table 5. Results of Health Symptoms Questionnaire[1] for Screen Print Workers by Level of Solvent Exposure

Exposure Category	Occasional/Frequent Solvent Exposure ($N=47$) N (%)[2]	No Exposure ($N=23$) N (%)	p for Difference
*Tire more easily	28 (60)	8 (35)	0.05
**Lightheaded/Dizzy	26 (55)	5 (21)	0.01
Trouble with written material	11 (23)	2 (9)	0.19
Depressed	21 (45)	6 (26)	0.13
Difficult to fall asleep	25 (53)	7 (30)	0.07
Sleeping more	10 (21)	3 (13)	0.50
*Loss of strength in arms/hands	12 (26)	0 (0)	0.01
Numb or tingling fingers	6 (13)	2 (9)	0.74
Numb or tingling toes	1 (2)	0 (0)	†
**Headaches more than once a week	31 (66)	1 (4)	<.01
*Low alcohol tolerance	14 (30)	2 (9)	0.05
**Headaches at work	34 (72)	9 (40)	0.01
Fatigue at work	30 (64)	10 (43)	0.11
**Intoxication or "high" at work	21 (45)	1 (4)	<.01
*Difficulty concentrating at work	16 (34)	2 (9)	0.02
*Dry skin	34 (72)	4 (40)	0.01
Persistent itch	8 (17)	1 (4)	0.20
Rash	3 (6)	0 (0)	†
Eye irritation	17 (36)	4 (17)	0.11
Vision difficulty	11 (23)	1 (4)	0.07
*Sore throat	19 (40)	4 (17)	0.05
Hoarseness	3 (6)	4 (17)	0.29

* $0.01 \leq p \leq .05$.
**$p < .01$.
[1]An edited version is presented here. Raw data available from the Field Research and Consultation Group, Department of Environmental Health.
[2]Percent of each group responding differently from "No" or "None".
†Cannot calculate p given distribution.

In small screen printing industries, process and cleanup variability appears to have a major effect on ambient daily exposure variation for solvents. For example, to determine whether sampling is representative of the full range of potential exposure conditions, the time spent in high-exposure activities, such as wash-up with solvents, needs to be separately sampled and evaluated. There are many sources of process variability within this industry, including the type of solvent used, type of printing performed, job size, and ventilation, which may influence solvent exposure concentrations. Specific work practices including the actual time spent in high exposure activities, the techniques and equipment used, and the location of the work will influence individual solvent exposure levels.

In this study, time study in conjunction with badge sampling was used to describe exposures in relation to activities performed. Time studies showed that the printing and washing tasks accounted for less then one third of the work day but were responsible for the majority of solvent exposure. Sampling in one of two workplaces (those with high ambient solvent levels) resulted in relatively high TWAs when the individuals personally performed little or no washing or printing. The use of time study in conjunction with traditional air sampling methods provides valuable insights for evaluation of the work tasks responsible for exposures. This combination of techniques is even more valuable in small industries where work tasks can be highly variable.

The results from the medical symptom questionnaire showed frequent reporting of central nervous system (CNS) symptoms among solvent-exposed workers and was consistent with results from other studies of the neurobehavioral effects of solvents exposures (6, 10). These symptoms include headache, dizziness, fatigue, and intoxication, as well as eye, throat, and skin irritation. Firm conclusions about solvent-induced toxicity in this industry will require larger, more detailed investigations which account for the potential confounding influence of other factors such as work schedules, medical history, and alcohol and drug use.

Because of the probability of frequent skin contact, confirmed by direct visual observations of solvent on unprotected hands and forearms, this route of absorption should be considered a contributing factor in any health effects. Reports of dry skin from 70% of the exposed group strengthen the conclusion that dermal exposure is a significant route of solvent exposure. These reports point out the necessity of evaluating dermal absorption on a quantitative basis. All future studies in this industry should utilize biological monitoring in addition to air sampling.

Among the eight small shops that were surveyed which used toluene, a consistent relationship was not found between time in high-exposure activity and the corresponding TWA for toluene. Engineering controls, such as ventilation and the types of materials used, presumably have a significant effect on the TWA. Individual estimates of TWA exposures in the industry cannot be predicted by work measurement or job descriptions alone.

CONCLUSION

Results from this study show that increased solvent exposures are experienced during the screen cleanup at the completion of a run. The close physical contact with solvents as the screen is manually cleaned, as well as from inhalation of solvent vapor, are responsible for this exposure. Short duration peak levels of over 2000 ppm total hydrocarbons were observed during continuous monitoring. These high peak levels typically occurred during screen cleaning.

General exhaust ventilation for these operations would greatly reduce the exposure of the worker and could reduce the solvent levels in the general print shop area. Ventilation control measures at the point of painting would be difficult to implement. Adequate ventilation of a work station would cause drying of ink in the screen, affecting print quality and process efficiency, and the operator would have to clean dried ink from the screen during the run more frequently due to the drying effect of the ventilation. However, the application of exhaust ventilation to drying racks for completed prints is feasible and could be used to reduce ambient levels of solvents. In addition, the use of organic cartridge respirators during the screen cleaning should further reduce the solvent exposure.

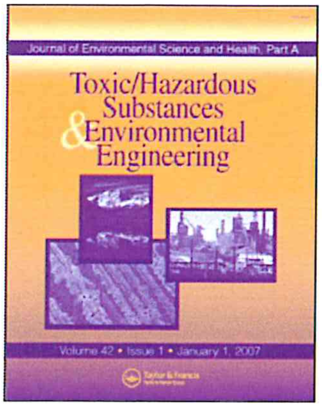
REFERENCES

1. Vihma, T. Health Hazards and Stress Factors in Small Industry – Prevalence Study in the Province of Uusimaa with Special Reference to the Type of Industry and the Occupational Title as Classifications for the Description of Occupational Health Problems. Scand. J. Environ. Health **1981**, *7*(Suppl. 3), 1–149.
2. Vihma, T.; Nurminen, M. Occurrence of Chemical Exposure in Small Industry in Southern Finland, 1976. Ann. Occup. Hyg. **1983**, *27*(3), 283–239.
3. Tuskes, P.M.; Key, M.M. Potential Hazards in Small Business – A Gap in OSHA Protection. Appl. Ind. Hyg. **1988**, *3*(2), 55–57.
4. O'Donnell, J.F. *Patterns of Organic Solvent Exposure in the Automotive Body Repair Industry*; Master's Thesis; Department of Environmental Health, University of Washington at Seattle, 1987.
5. Daniell, W.; Stebbins, A.; Kalman, D.; O'Donnell, J.F.; Horstman, S.W. The Contributions to Solvent Uptake by Skin and Inhalation Exposure. Am. Ind. Hyg. Assoc. J. **1992**, *53*(2), 124–129.
6. NIOSH. *Health Hazard Evaluation, Screen Printing Shops*, HETA 82-212-1553; U.S. Department of Health and Human Services, Centers for Disease Control, NIOSH: Cincinnati, OH, 1982.
7. Baelum, J.; Anderson, I.; Molhave, L. Acute and Subacute Symptoms among Workers in the Printing Industry. Br. J. Ind. Med. **1982**, *39*(1), 70–75.
8. Silberschmind, M. Solvent Toxicity among Female Silk Screen Printers. Presented at the International Conference on Solvent Toxicity, Stockholm, Sweden, November 1984.
9. Ng, T.P.; Ong, S.G.; Lam, W.K.; Jones, G.M. Neurobehavioral effects of Industrial Mixed Solvent Exposures in Chinese Printing and Paint Workers. Neurotoxicol. Teratol. **1990**, *12*, 661–664.
10. White, R.F.; Proctor, S.P.; Echeverria, D.; Schweikert, J.; Feldman, R.G. Neurobehavioral Effects of Acute and Chronic Mixed-Solvent Exposure in the Screen Printing Industry. Am. J. Ind. Med. **1995**, *28*, 221–231.

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

11. NIOSH. *Manual of Analytical Methods, Third Edition,* PCAM 1500/1501; U.S. Department of Health and Human Services, Centers for Disease Control, NIOSH: Cincinnati, OH, 1997.
12. ACGIH. *Threshold Limit Values 1996*, American Conference of Governmental Industrial Hygienists; Cincinnati, OH, 1996.
13. *AID Model 710: Portable Total Hydrocarbon Analyzer,* Thermo Electron Instruments; Hopkinton, Maine, 1988.

Received May 2, 2001



Journal of Environmental Science and Health, Part A
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597268

SOLVENT EXPOSURES IN SCREEN PRINTING SHOPS

Sanford W. Horstman [a]; Steven R. Browning [a]; RaeAnne Szeluga [a]; Jennifer Burzycki [b]; Arlene Stebbins
[a] Department of Preventive Medicine and Environmental Health, University of Kentucky, Chandler Medical Center, Lexington, KY, U.S.A. [b] Boeing Commercial Airplane Company, Seattle, WA, U.S.A.

Online Publication Date: 30 November 2001

To cite this Article Horstman, Sanford W., Browning, Steven R., Szeluga, RaeAnne, Burzycki, Jennifer and Stebbins, Arlene(2001)'SOLVENT EXPOSURES IN SCREEN PRINTING SHOPS',Journal of Environmental Science and Health, Part A,36:10,1957 — 1973

To link to this Article: DOI: 10.1081/ESE-100107440

URL: http://dx.doi.org/10.1081/ESE-100107440