

VOC Exposures in a Mixed-Use University Art Building

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Despite a sizable educational art enterprise in the United States there is a dearth of rigorously performed studies of exposures to persons engaged in such activities. Exposures to 45 EPA-designated volatile organic compounds were examined in printmakers in a mixed-use university art school served by a 100% exhausted mechanical ventilation system. Personal exposures ($n=90$) were compared with area concentrations ($n=36$) in the studio area and at a second location at the same facility. For personal exposure assessments a cohort of 12 students wore passive dosimeters twice weekly over a 6-week period. Numerous compounds were found, the most prevalent being toluene at an average concentration of $64.6 \mu\text{g}/\text{m}^3$ (17.1 ppb; range $<1-319$ ppb); 1,1,1, trichloroethane at $40.5 \mu\text{g}/\text{m}^3$ (7.5 ppb; range $<1-211$ ppb); xylenes at $8.0 \mu\text{g}/\text{m}^3$ (1.8 ppb; range $<1-43$ ppb); 1,3,5-trimethyl benzene at $6.2 \mu\text{g}/\text{m}^3$ (1.3 ppb; range $<.3-32$ ppb); propyl benzene at $5.0 \mu\text{g}/\text{m}^3$ (1.0 ppb; range $<.5-27$ ppb); methylene chloride at $4.9 \mu\text{g}/\text{m}^3$ (1.4 ppb; range $<1-10$ ppb); and ethyl benzene at $4.5 \mu\text{g}/\text{m}^3$ (1.1 ppb; range $<.4-23$ ppb). Personal exposures were considerably higher than average area air concentrations, with the exception of methylene chloride concentrations, which were five times higher at the print cleaning operation. Floors where solvents were not used had no detectable exposures (typical lower limit of detection ≈ 1 ppb) and were free of solvent odors. Despite frequent solvent contact with skin, personal protective equipment was seldom used. Results indicate that in mixed-use facilities such as this, nonrecirculating general ventilation systems can effectively eliminate indoor air quality issues between floors, despite perceptible odors on solvent use floors. For total exposure assessments in such processes, contact exposures from printmaking solvents during cleaning procedures are a potentially important consideration.

Keywords: art, indoor air quality, organic vapor monitor, printmaking, total volatile organic compounds, volatile organic compounds

Printmaking can be a solvent intensive process resulting in exposures to those who practice the art or otherwise work in shared facilities. Despite instruction in the printmaking process at both the high school and college level, there is surprisingly little information on actual student exposures resulting from the process. The toxic properties of art materials are widely ranging, from corrosive mists of acid etches to low-toxicity spray fixatives.⁽¹⁾ Because of the inhalation risk, as well as their effect on general indoor air quality (IAQ),⁽²⁾ volatile organic compounds (VOCs) were the focus of this study.

According to the *Occupational Outlook Handbook*,⁽³⁾ visual artists (including fine artists,

sculptors, printmakers, illustrators, and graphic designers) held about 308,000 jobs in 1998. Of these employees nearly 6 of 10 were self-employed. Within the visual artist classification, most work was performed in the two job categories of job printer and printing machine operator, with 45,850 and 208,980 employees, respectively. Although there are no estimates available of art students exposed to similar operations in U.S. art schools, it is difficult to become skilled enough to make a living as a visual artist without some formal training.⁽³⁾ Therefore, it is probable that many professional printmakers were first exposed to art material hazards in college or secondary education institutions.

Since the 1970s exposures to all industrially

important solvents has declined significantly.⁽⁴⁾ Paradoxically, the total number of personal breathing zone samples collected to assess these exposures has increased by a factor of a thousand, and the number of papers written concerning solvent exposures has increased by almost fivefold.⁽⁴⁾ The printing industry is one in which workers' exposures to toluene and xylene are reported to be consistently in excess of both the threshold limit value (TLV) or one-half the TLV designated for those solvents.⁽⁴⁾ For these reasons it is important to assess the magnitude of exposures from similar processes in secondary schools and colleges.

The hazards of small-scale or educational art production may be overlooked or ignored by students, teachers, or staff working in such areas. Few (if any) empirical studies have been reported concerning volatile organic compound (VOC) exposures received by such persons. Existing work has been limited to basic reviews of material hazards associated with various media or techniques⁽⁵⁻⁷⁾ or to large commercial production (e.g., 470 g/hour average VOC emission rate).⁽⁸⁾ Descriptions of student artists' "exposures" to solvents have not examined actual airborne exposures from process or cleaning operations or addressed the impacts of solvent odors in unrelated (i.e., "mixed use") areas.

PRINTMAKING PROCESS

The printmaking process has various steps depending on the desired visual outcome. Both etching and lithography were being carried out in the studied location. Etching involves preparation of the image, printing the image, and cleaning. Etching of the image is accomplished using tools to carve the design into a metal plate. Once designed, the plate is soaked in an acid bath, rinsed with water, and then covered in a rosin powder. Next, the plate is placed onto a heated surface to melt the rosin. It is then returned to the acid bath and again rinsed. The completed master image plate is used to create prints by pouring a mix of ink and mineral oil onto its surface and rolling it through a paper press. When a printing run is completed, the plate is taken to a cleaning station, where it is wet-wiped using a cloth saturated with kerosene. For a heavily soiled plate, the kerosene is allowed to sit uncovered on the plate to facilitate easier wet wipe cleaning.

Lithography is functionally the reverse process of etching. It is a simpler, surface process in which an image is placed on to a stone or metal substrate with a paraffin crayon or ink. The entire piece is then treated with turpentine and water, after which ink is applied to the design. A print is made by pressing paper to the lithographic surface. Depending on the desired effect, the artist may serially employ etching or lithography for a single finished piece. For a detailed review of these processes, the reader is referred to Stokstad.⁽⁹⁾

Hazards and Issues

Printmaking is frequently taught in high schools, colleges, and vocational schools throughout the United States. In many such facilities the printmaking process is only one of numerous uses of the building in which it is performed, resulting in the potential for IAQ issues related to such mixed use. Although solvent odors from etching and lithography may be discounted by those working directly with art materials, if not adequately controlled these substances may cause air quality concerns among those sharing space with art operations. A review of the hazards of specific art materials is presented by Babin et al.⁽¹⁰⁾ and McCann.⁽¹¹⁾

Presently in the United States there are few binding standards

for most VOCs in nonindustrial indoor occupancies such as colleges and universities.⁽¹²⁾ However, a strategy aimed at the reduction of environmental contaminants in schools is a developmental goal of the environmental health objectives listed in *Healthy People 2010*, the major long-term funding blueprint for the U.S. Department of Health and Human Services.⁽¹³⁾ Specifically, it has been proposed to "Increase the proportion of the Nation's primary and secondary schools that have official school policies ensuring the safety of students and staff from environmental hazards, such as chemicals in special classrooms, poor indoor air quality, asbestos, and exposure to pesticides."^(sec. 8, p. 26) Toward this end, estimates of the impacts of teaching art classes in such mixed-use facilities will be essential.

Any discussion of VOC hazards in printmaking must include kerosene, because it is the most common solvent used for the cleanup of art tools and screens (and sometimes skin). Kerosene components can be found in most proprietary cleaning products that are used in printmaking. Due to the large amount of solvent used, cleanup can be the most hazardous process in printmaking. Solvent-soaked rags are often found lying near cleaning stations.

Kerosene is a refined petroleum solvent with a boiling range of 175–325°C (347–617°F) and a variable flashpoint (closed cup) of between 38 and 74°C (100–165°F).⁽¹⁴⁾ It is a complex mixture of aliphatic, naphthenic, and alkylated aromatic hydrocarbons with chain lengths that range from C9 to C16. Synonyms for kerosene include astral oil, coal oil, and no. 1 fuel oil. In addition to printmaking it is used as a carrier for pesticides; a weed killer; a mold release agent in the ceramics and pottery industry; and in asphalt coatings, enamels, paints, thinners, and varnishes.

Health issues associated with exposure to kerosene include toxicity to the nervous system, reproductive system damage, liver and kidney damage, respiratory impairment, and dermatitis.⁽¹⁴⁾ It is poisonous if ingested, may cause dermatitis after skin contact, and inhalation of large quantities may cause lung irritation and chemical pneumonia if aspirated.⁽¹¹⁾ The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit for kerosene is 100 mg/m³ of air for up to a 10-hour work shift in a 40-hour workweek.⁽¹⁵⁾

In this study a studio-based college printmaking course was examined. Students and faculty worked in the building 20 to 30 hours per week, engaging in activities using volatile chemicals that contaminated the air of the process room and floor. Courses were offered year-round during which times fresh air from open windows was variable. On entering the printmaking floor, a strong odor could be noticed, although those staying in the building for a short length of time rapidly acclimated to these odors. Such dynamic conditions can potentially allow occupants of the building to be exposed to elevated VOC levels without an appreciation of potential hazards, as well as generate concerns among those residing on adjacent floors not involved with any specific art process.

METHODS

Sampling

Personal and area sampling was performed in this study using the 3M 3500 passive organic vapor monitor (OVM; 3M, Inc.; St. Paul, Minn.). Use of the device has been validated by NIOSH for diffusive sampling of toluene, one of the most significant volatile components of kerosene,⁽¹⁶⁾ and it has been used successfully for

the evaluation of VOC contamination in indoor air quality issues.⁽²⁾ This dosimeter has been extensively evaluated and found suitable for use as an area sampler given adequate exposure time.⁽¹⁷⁾

Personal sampling was conducted in areas performing ink work (mainly silk screening) and cleaning during the climatically moderate months of September and October. The participants in this study were a cohort of 12 graduate students and 1 faculty member. Samples were collected on nine occasions over a 6-week period (typically twice a week), each time for approximately 3 hours during a studio printmaking session. The limit of detection varied for each compound and was typically in the range of 0.5–1.5 ppb.

Area samples from the mechanically ventilated printmaking floor and a separately ventilated, non-art-related floor three levels higher also were collected each sampling day ($n=36$), as were field blanks ($n=18$). Dosimeters used for area samples were placed in the same location on each sampling date. Two area samples were taken each sampling day in the second-floor studios. One was located near the cleaning station, and the other was located in the middle of the studio. Concomitantly, two dosimeters were placed on the fifth floor at opposite ends of a hallway. A bulk sample was obtained from the studio's kerosene supply for analytical identification of its major VOC components. The compounds identified in the kerosene would be compared to those found in the personal and area samples. After collection, samples were kept refrigerated to $<10^{\circ}\text{C}$ and analyzed within 2 weeks of their collection.

Analysis

OVM charcoal sampling pads were desorbed after their removal from the OVM using a procedure adapted from Stock and Morandi.⁽¹⁷⁾ Each pad was processed individually by immediately placing it in a 2.0-mL amber crimp vial (HP, Wilmington, Del., #5181-3376). A gastight 1.0-mL syringe (Hamilton, Reno, Nev., #1001) was used to add 1.0 mL of 99.9+ pure carbon disulfide (Aldrich Chemical, St. Louis, Mo., #42,464-1, lot #LU 06855LU) to the vial. The vial was then capped using a crimping tool and the cap tightness physically verified. The vial was then placed in an ice water bath and sonicated for 40 min. After desorption, 200 μL of sample was removed from the vial using a 250- μL syringe with set-stop (Hamilton, #725), and placed in a second amber 2-mL vial containing a vial insert (HP, #631-9330). Using a 25- μL syringe (Hamilton, #702), 10 μL of a 10- $\mu\text{g}/\mu\text{L}$ internal standard mix of pentafluorobenzene, 1,4-difluorobenzene, chlorobenzene, and 1,4-dichlorobenzene (Absolute Standards; Hamden, Conn.) was added to the vial. The vial was then crimp-capped and immediately placed into an auto sampler tray pending analysis.

Samples were qualitatively and quantitatively analyzed using a Hewlett-Packard 6890 gas chromatograph coupled to a Hewlett-Packard 5973 mass spectrometer. Analytes were separated with a 90 m \times 0.32 mm bore HP-VOC special performance capillary column coated to a 1.8 μg liquid film thickness (HP, #19091R-319). Run parameters were similar to those used by Stock and Morandi for analysis of 3M dosimeters employed as area samplers.⁽¹⁷⁾ Briefly, an injector port temperature of 180°C was used with an initial oven temperature of 35°C and an 8-min hold, followed by a ramp rate of $8^{\circ}\text{C}/\text{min}$ to 180°C , and then $20^{\circ}\text{C}/\text{min}$ to a final temperature of 270°C with a 7-min hold. Total run time for each analysis cycle was 37.6 min.

The VOC standards mix (Ultra Scientific, North Kingstown, R.I., #DWM-588) used for quantification is marketed for EPA Method 8260B (and others). That method is primarily used in air

and water sampling to determine VOCs from a variety of solid matrices, including halogenated and nonhalogenated organics. For that reason the VOCs employed in that method were deemed appropriate for use in this study for both the OVM and bulk samples. Not all compounds of the mix can be discriminated by the column, desorption solvent, and run parameters used in this study. Table I lists the 60 compounds included in the standards mix and the 45 chemicals this method was able to resolve.

Following analysis, sample results were reviewed for accuracy in an operational step HP has termed "Qedit." Qedited results were then entered into a spreadsheet to calculate the amount of a VOC in the air in micrograms per cubic meter and parts per billion, employing exposure time and 3M supplied sampler desorption coefficient and sampling rate for a given chemical.⁽¹⁸⁾ Of the 45 standard components detectable in this study, there were 20 for which 3M OVM desorption coefficients and sampling rate data were available. These are indicated as "Quantified Compounds" in Table I. An additional 25 chemicals in the standard mix were identified and semiquantitatively reported using the average desorption coefficient (0.915) and average sampling rate (30.9 mL/min) calculated for all chemicals for which 3M reported such parameters ($n=127$). These are indicated as "Semiquantified Compounds" in Table I. Thus, of the 60 compounds in the standard mix, 45 can be resolved by the method used, 20 can be positively quantified, and 25 can be semiquantified.

Volatile compounds present in the kerosene used in the studio, as determined by direct injection of a 1- μL kerosene sample onto the column, are listed in Table II. Chemicals were considered de facto volatile if they were included in the standard VOC mix utilized for the study. Substances listed as volatile in Table II served as positive marker compounds in the study, in that when such compounds were detected in studio air their presence could reasonably be attributed to the kerosene employed in the studio processes.

RESULTS

Average personal VOC exposures were greater than average area concentrations (Table III). Personal exposures to toluene, trichloroethane, xylenes, propyl benzene, and 1,3,5-trimethyl benzene were all higher than area concentrations. Four of these compounds were significant components of the kerosene used in the studio. There were some notable exceptions in which area concentrations exceeded personal exposures. One was methylene chloride, for which the area sampler located adjacent to the cleaning station had higher levels (area concentration $27.21 \mu\text{g}/\text{m}^3$ versus $4.88 \mu\text{g}/\text{m}^3$ personal exposure). Also, area concentrations of trichloromonofluoro methane exceeded personal concentrations on both floors. Neither methylene chloride nor trichloromonofluoro methane were detected as kerosene constituents, and so their presence is attributed to solvents used elsewhere on the second floor. Plausible process areas include a silk screening room and a painting studio, although no attempt was made to inventory the solvents at those locations.

Except for toluene, the fifth floor, where solvents were not used, had overall lower area concentrations than the studio arts floor (second) and was free of solvent odors. For all quantified compounds except toluene, the fifth floor had ambient concentrations less than one-third those of the solvent-use floors. Personal exposures to toluene on the studio art floor were three times

TABLE I. VOCs Available to EPA Method 8260 B in Standard Mix, Quantified, and Semiquantified

Compound Name	Standard Mix (n = 60)	Quantified (n = 20) ^a	Semiquantified (n = 25) ^b
Benzene	X	X	
Bromobenzene	X		X
Bromochloromethane	X	X	
Bromodichloromethane	X		X
Bromoform	X		X
Bromomethane	X		
n-Butylbenzene	X		
Carbon tetrachloride	X	X	
Chlorobenzene	X	X	
Chlorodibromomethane	X		X
Chloroethane	X		
Chloroform	X	X	
Chloromethane	X		
2-Chlorotoluene	X		
4-Chlorotoluene	X		
1,2-Dibromo-3-chloropropane	X		X
1,2-Dibromoethane	X		X
Dibromomethane	X		X
1,2-Dichlorobenzene	X	X	
1,3-Dichlorobenzene	X	X	
1,4-Dichlorobenzene	X		
Dichlorodifluoromethane	X		
1,1-Dichloroethane	X	X	
1,2-Dichloroethane	X		X
1,1-Dichloroethene	X	X	
trans-1,2-Dichloroethene	X		X
cis-1,2-Dichloroethene	X		X
1,2-Dichloropropane	X		X
1,3-Dichloropropane	X		X
2,2-Dichloropropane	X		X
cis-1,3-Dichloropropene	X		X
trans-1,3-Dichloropropene	X		X
1,1-Dichloropropene	X		X
Ethylbenzene	X	X	
Hexachlorobutadiene	X		X
Isopropylbenzene	X		
4-Isopropyltoluene	X		
Methylene chloride	X	X	
Naphthalene	X	X	
n-Propylbenzene	X		X
sec-Butylbenzene	X		
Styrene	X	X	
1,2,3 tert-Butylbenzene	X		X
1,1,1,2-Tetrachloroethane	X		X
1,1,1,2,2-Tetrachloroethane	X	X	
Tetrachloroethylene	X		X
Toluene	X	X	
1,2,3-Trichlorobenzene	X		X
1,2,4-Trichlorobenzene	X		X
1,1,1-Trichloroethane	X	X	
1,1,2-Trichloroethane	X	X	
Trichloroethylene	X	X	
Trichloromonofluoromethane	X		X
1,2,3-Trichloropropane	X		
1,2,4-Trimethylbenzene	X		
1,3,5-Trimethylbenzene	X		X
Vinyl chloride	X		
o-Xylene	X	X	
m-Xylene	X	X	
p-Xylene	X	X	

^am- and p-xylene coelute and so are considered as a single compound for the purposes of categorization.

^bSee text for criteria of "semiquantified" compounds.

TABLE II. Volatile Compounds Present in Studio Kerosene

Volatile Compounds	% Relative Abundance ^a
Benzene	0.09
Toluene	3.83
1,1,2,2-tetrachloroethane	4.0
Ethylbenzene	6.71
1,2,3-tert-butylbenzene	7.8
Naphthalene	12.1
O-xylene	12.7
Propylbenzene	13.6
1,3,5-trimethylbenzene	19.5
M-xylene, P-xylene	19.7

^aAbundance indicates percentage of total compounds relative to standard VOC mixture utilized in study. Nonvolatile components of sample are not indicated.

greater than studio art floor area concentrations, and approximately 50% higher than area concentrations on floors where solvents were not used.

DISCUSSION

Wadden et al.⁽⁸⁾ detected total VOCs (TVOC) in a commercial print shop ranging from 50.14 to 109.57 mg/m³ for 12-hour sampling periods. Speciation of the VOCs present indicated that toluene, p-ethyl-toluene, o-ethyl-toluene, and aromatic C-9s were largely responsible for the levels reported, regardless of location within the facility. As can be seen in Table III, TVOC personal levels in this study (i.e., 180.56 µg/m³, based on the summation of the VOC species detected) were much lower. TVOC values were approximately one-fifth those reported by Weschler et al.⁽²⁾ in a building exhibiting sick building syndrome.

The TVOC concentrations reported here are comparable with other studies examining TVOC relevance to IAQ issues. However, Batterman and Peng⁽¹²⁾ correctly noted that the method of TVOC assessment can lead to "considerable differences in reported TVOC concentrations."^(12, p. 62) Thus, the utility of the TVOC data included here is relative to other studies employing similar methods for TVOC reporting. In this study there is a strong correspondence between the VOCs detected in studio air and their presumptive source (Tables II and III).

In one corner of the studio location a small (10 foot by 5 foot), separate 100% exhausted room was available for processes generating noxious odors (e.g., lithographic etching of copper or zinc are known to generate acid mists).⁽¹⁾ This room drew its makeup air from the studio location sampled in this study and so would be expected to decrease VOC concentrations in the studio somewhat. However, in the course of this study the exhausted room was generally not used, perhaps because of the mild outdoor temperatures, which allowed main studio windows to be fully and continuously open. Levels of VOCs detected in this study probably would have been higher in winter months when studio windows could be expected to remain closed.

Solvent odors were perceptible in the studio and on the studio floor, but not on the floor where solvents were not used. Despite the relatively higher area toluene levels on the non-solvent use floor, concentrations were still below odor thresholds (Table IV). It is possible that the cause of the odors on the studio floor was the TVOC concentration or transient peaks of certain species with low odor thresholds. Xylenes in particular were detected at concentrations exceeding the odor threshold.

Several plausible explanations for the higher ambient toluene

TABLE III. Compounds Detected by Sample Location (Ranked by Personal Exposure)

Compound	Personal Exposure ($\mu\text{g}/\text{m}^3$)			Studio Floor Concentration ($\mu\text{g}/\text{m}^3$)			Non-Use Floor Concentration		
	Average (n = 90)	Median (n = 90) ^A	Standard Deviation	Average (n = 18) ^A	Median (n = 18) ^A	Standard Deviation	Average (n = 18)	Median (n = 18) ^A	Standard Deviation
Toluene	64.6	38.6	173.1	16.5	29.1	26.7	40.6	39.8	53.9
1,1,1-Trichloro-ethane	40.5	3.4	147.3	24.6	3.1	40.1	1.4	1.6	1.1
Trichloromonofluoro methane	23.2	21.6	35.4	25.3	22.2	47.4	38.1	28.2	43.8
m-Xylene, p-xylene	8.4	3.2	21.6	4.4	5.5	3.9	3.3	2.4	6.0
o-Xylene	7.6	3.4	18.8	4.5	5.5	3.1	1.6	2.2	3.4
1,3,5-Trimethyl-benzene	6.2	2.1	20.8	4.2	3.8	4.1	0.4	<LOD	0.8
Propyl-benzene	5.0	2.9	13.0	3.6	5.1	2.7	0.3	<LOD	0.9
Methylene chloride	4.9	2.6	8.4	27.2	9.6	48.0	0.2	<LOD	0.5
1,1,2,2-Tetrachloro-ethane	4.8	1.9	7.7	4.9	3.3	3.4	1.1	1.5	1.6
Ethylbenzene	4.6	2.6	11.8	3.2	3.0	2.5	2.1	1.1	3.9
1,2,3-Tert-butyl-benzene	2.6	<LOD	8.9	2.1	2.1	2.0	0.3	<LOD	0.7
1,3-Dichloro-benzene	2.0	2.3	3.1	0.4	0.8	4.8	0.8	<LOD	3.3
Carbon tetrachloride	1.5	2.8	1.0	1.6	2.7	1.1	1.1	2.5	1.6
Naphthalene	1.0	<LOD	3.2	<LOD	<LOD	20.1	0.2	<LOD	2.6
Chloroform	0.9	<LOD	2.3	0.1	<LOD	0.4	0.1	<LOD	0.4
1,2-Dibromo-3-chloropropane	0.7	<LOD	2.5	1.4	1.0	3.5	0.2	<LOD	3.2
Tetrachloro-ethylene	0.7	<LOD	2.3	0.4	<LOD	1.1	0.4	<LOD	1.2
Trichloro-ethylene	0.5	<LOD	0.9	0.2	<LOD	0.9	0.3	<LOD	0.6
Benzene	0.4	<LOD	6.2	2.8	2.9	7.7	2.3	2.3	6.4
1,3-Dichloro-propane	0.3	<LOD	0.8	0.5	<LOD	0.8	0.2	<LOD	0.5
1,2,3-Trichloro-benzene	0.1	<LOD	0.5	0.3	<LOD	0.8	0.1	<LOD	0.4
TVOC	180.6	87.4		128.4	99.6		95.2	81.6	

^ALOD = limit of detection. The LOD varied by compound and was typically in the range of 0.5–1.5 ppb.

concentrations on the fifth floor can be offered. The average reported was strongly influenced by a single elevated concentration on one sampling day. This data point was retained in the calculation of compound averages as there was no compelling reason to exclude it. It is possible that an unrecognized source was present on this elevated day and an acclimated person removing the sampler failed to detect its presence. A second possibility for the higher fifth-floor toluene values may be the sampling times employed for the OVMs. Although the OVMs utilized were shown to give acceptable results under most conditions when used as area

samplers, variability has been shown to increase with sampling times less than about 48 hours.⁽¹⁷⁾ Variability is more noticeable at the lower concentrations typical in this study. Finally, the study building was built into the side of a hill such that the fifth floor opened directly onto a parking lot. It is conceivable that on one or more days toluene vapors from the asphalt or the cars driven on it made their way to the sampling device.

Peaks in compound concentrations were most likely due to solvent use during the cleaning process, although precise activities of the students were not recorded in a time-activity log. The area monitoring suggests that the higher concentration levels on personal badges were from working near or at the cleaning station where kerosene was used. Solvent soaked cloths were regularly used and left uncovered to dry in this area of the studio, and there was no local exhaust system at this location. Despite frequent solvent splashes and skin contact, there was minimal use of personal protective equipment. The cleaning area of the studio in particular indicated a high potential for dermal exposure to the solvents used.

CONCLUSIONS

Exposures were low and well below existing occupational limits for 40-hour exposures. In mixed-use facilities where print making operations share space with unrelated work areas, even these low levels could be the basis for complaints. Faculty members who work in or around the studios are constantly exposed for at least 40 hours per week to the VOCs examined in this study. The significance of these low exposures, in particular to teenaged persons routinely present, in mixed-use facilities is unknown. For a student progressing into an occupation such as visual artist, it is important to note the existence of such an early-career exposure scenario, albeit low.

This study is the first to examine student personal exposures to

TABLE IV. Odor Thresholds of Selected Volatile Organic Compounds

Compound	Odor Threshold (Detection) ppm ^A	Odor Threshold (Recognition) ppm ^A
1,1,1-Trichloro-ethane	390	710
1,1,2,2-Tetrachloro-ethane	7.3	n/a
1,3,5-Trimethyl-benzene	2.2	n/a
Benzene	61	97
Carbon tetrachloride	252	n/a
Chloroform	192	n/a
Ethylbenzene	n/a	n/a
m-Xylene	0.62	n/a
p-Xylene	2.1	n/a
Methylene chloride	160	230
Naphthalene	0.038	n/a
o-Xylene	5.4	n/a
Propyl-benzene	n/a	n/a
Tetrachloro-ethylene	47	71
Toluene	1.6	11
Trichloro-ethylene	82	110
Trichloro monofluoromethane	n/a	209

^An/a: not available.

Source: *Odor Thresholds for Chemicals with Established Occupational Health Standards*. Akron, Ohio: American Industrial Hygiene Association (1989).

VOCs, and to demonstrate a difference in VOC concentrations between working and cleaning areas of a university printmaking studio. Levels found are low when compared with those seen in production settings. Differences between the art process floor and a separately ventilated floor also were seen. The efficacy of the nonrecirculating heating, ventilating, and air-conditioning system in preventing odors and most cross-contamination was demonstrated. This finding should be noted if additional steps are taken to establish school policies designed to protect students and staff from environmental hazards such as chemicals in special classrooms or poor IAQ.

Although dermal exposures were not rigorously evaluated, observations indicate that contact exposures from printmaking and cleaning processes may be more important than breathing zone exposures. Students and faculty should be wearing gloves when cleaning to minimize the chance of ingesting any of the cleaning solvent. They should also wear eye and face protection when working at the cleaning station. Minimizing the likelihood of inhalation and ingestion will greatly reduce personal exposures.

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