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The Control of Press Cleaning Solvent Vapors in a Small Lithographic Printing Establishment

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Small businesses frequently have inadequate in-house expertise to solve a variety of safety and health problems. The National Institute for Occupational Safety and Health (NIOSH) has therefore conducted a demonstration project in the commercial lithographic printing industry, which consists largely of small companies, in an effort to establish suitable control technology for airborne solvent vapors released primarily during press cleaning operations. These solvent vapors have a number of potential adverse health effects, including narcosis, kidney and liver damage, and cancer. Also, airborne anti-offset powder is a potential allergic sensitizer and cause of occupational asthma. As a means of controlling worker exposures to the vapors and dust, a local exhaust inlet was attached to the side of the press adjacent to the paper delivery point. Tempered outside air was introduced through ceiling outlets installed to make up for the exhausted air. Measurements of press operator exposure and area concentrations of solvent vapors and area concentration of anti-offset powder were made before and after installation of the new ventilation controls. Vapor concentrations were reduced by 73 percent for the press operators. Area concentrations of the vapors were reduced by 86 percent and dust concentration by 67 percent. The ventilation system was found to be suitable for vapor and dust control, although substitution of a cleaning solution containing non-carcinogenic solvents for solutions containing carcinogens was recommended.

Keywords Lithographic Printing, Ventilation Controls, Cleaning Solvents, Anti-Offset Powder

This article reports the results of a control technology demonstration study in which personal exposure and area sampling for airborne solvent vapors was conducted at a small lithographic printing establishment (approximately 10 full-time employees) during two periods in August and September 1995. Between the sampling periods, a local exhaust system, with provision for fresh make-up air, was installed to serve two of the three operating presses. The fresh air entered the press room through ceiling inlets added exclusively for it. An air-to-air heat exchanger (Raydot, Incorporated, Cokato, Minnesota) was included to improve the energy efficiency of the system. The sampling data provided a basis for evaluating the effectiveness of the fresh air system in reducing personal exposures to the airborne solvent vapors. This article also includes process description, health effects discussion, the sampling methods, ventilation flow measurements, and some recommendations for follow-up work.

This case study is part of a larger study that the National Institute for Occupational Safety and Health (NIOSH) is conducting in the small business (i.e., with less than 20 employees) segment of the commercial printing industry. The study proposes to reduce lithographic printers' airborne exposures to cleaning solvent vapors.

The small business segment accounted for about 81 percent of the establishments in the printing and publishing industry in 1992.[1] There also were a number of printing techniques in common use, but the lithographic process accounted for about 77 percent of the establishments and employees involved in commercial printing.[1]

PROCESS DESCRIPTION

A diagram of an offset lithographic printing press is shown in Figure 1.

The image to be printed, in the form of a flexible plate, is attached to the plate cylinder. The image area, the portion of the plate that is to receive ink, is made hydrophobic or grease-receptive. The areas that are not intended to receive ink are made hydrophilic or water-receptive. The fountain solution, containing water, buffer, gum arabic or synthetic resin, wetting agents, and other additives, dampens the water-receptive areas as the plate cylinder turns. The ink adheres only to the hydrophobic, grease-receptive areas. The image is transferred from the plate, first to a rubber-covered cylinder called the blanket, and from there to the paper or other substrate.

To maintain good quality prints, the blanket and the plate must be kept free of dust and debris, and there must be no ink

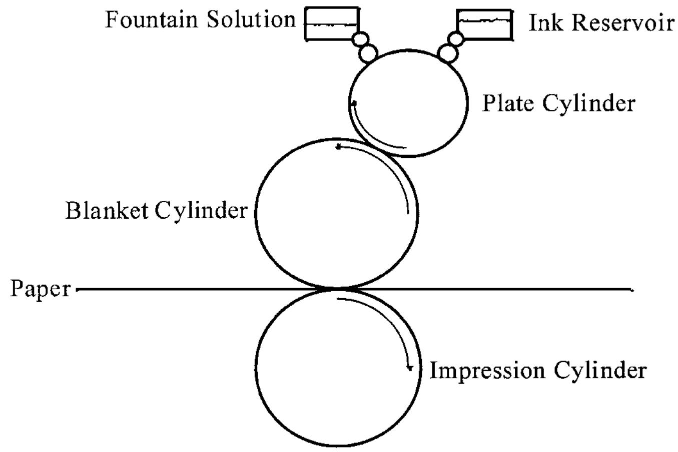

FIGURE 1
Offset lithographic printing diagram.

in the non-image areas. For small presses, the press operators periodically carry out the necessary press cleaning operations by hand during or between printing runs, using solvent-soaked wipers. The cleaning fluids are typically a mixture of several organic solvents, which are selected in part for high evaporation rates so that the printing process can be resumed quickly, as soon as the blanket and plate are dry. Residual solvent can interfere with the printing process.

For sheetfed presses, the usual type in the small business segment, after single sheets are printed, they land in a stack on one side of the press. If the ink has not set adequately, ink from the previous sheet can be transferred to the back of the next sheet as it falls onto the stack. To avoid this undesirable result, anti-offset powder can be automatically sprayed onto the front of each sheet after it is printed and as it falls onto the stack. Anti-offset powder permits a significant increase in press speed. The powder is extremely fine, like talcum powder, and is usually vegetable-based (ground potato or corn starch, for example). If no measures are taken to contain it, the powder will escape from the presses to settle on top of all exposed surfaces in the press room, which is usually considered a housekeeping nuisance.

HEALTH AND SAFETY CONSIDERATIONS

A small number of the compounds used as press cleaning solvents are potential human carcinogens, including benzene, methylene chloride, and perchloroethylene. Adverse health effects typical of the organic solvents used in press cleaning solutions include headache, nausea, vomiting, dizziness, respiratory failure, central nervous system depression, coughing, difficulty breathing, chest pains, narcosis, unconsciousness, and death. Chronic effects include kidney and liver damage. The principal adverse health effect of the great majority of the cleaning compounds is narcosis.

The anti-offset powder typically consists of raw ground corn or potato starch, which are potential allergic sensitizers. The starches also have severe indices of ignition sensitivity and explosion severity,[2] although the minimum explosive concentration (30–50 g/m^3)[2] is several orders of magnitude above the airborne concentrations expected in printing applications. Potato starch has a Class 2 flammability rating, characterized by local combustion of short duration.[3]

STANDARDS FOR MIXED EXPOSURES

Even when no individual compound exceeds an Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL), a NIOSH Recommended Exposure Limit (REL), or an American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV®), the additive exposure of a mixture of vapors can exceed one or more of these standards of acceptability. In the absence of evidence to the contrary, it is standard industrial hygiene practice to consider concurrent exposures to two or more hazardous substances which act upon the same target organ system as an additive exposure, and to use the additive rule for calculation of the appropriate additive PEL (or REL or TLV).[4,5] For example, if a cleaning solution contained four compounds, each of which were individually present in the workroom air at 0.3 times their individual 8-hour time-weighted average (TWA) PEL and all had similar adverse health effects, then the additive exposure would be 1.2 times the additive PEL. NIOSH recommends that certain provisions of the OSHA health standards, such as periodic employee exposure monitoring and training of employees, be initiated at 50 percent of the PEL, defined as the action level.[6]

MOTIVATION FOR THE DEVELOPMENT OF CONTROLS IN THE PRINTING INDUSTRY

Many compounds are used for the press cleaning operations. Each cleaning solution is normally a mixture of several organic compounds. A partial list of the potentially toxic cleaning compounds found by NIOSH researchers from 1972 to 1995[7] is given in Table I. In addition, mixtures such as Stoddard solvent, mineral spirits, naphtha, kerosene, and aliphatic and aromatic hydrocarbons are frequent components of cleaning solutions.

Generally, the concentration of any one compound, as determined by 8-hour TWA personal sampling during the NIOSH

TABLE I
Some compounds found in press cleaning solutions

Acetone	Ethyl benzene	Naphthalene
Benzene[A]	Hexane	Perchloroethylene[A]
Butoxyethanol	Isobutanol	Propyl alcohol
Cumene	Isopropanol	Toluene
Cyclohexanone	Methanol	Trichloroethane
Ethanol	Methylene chloride[A]	Trimethylbenzene
Ethoxyethanol	Methyl ethyl ketone	Xylene
	Methyl isobutyl ketone	

[A]These compounds have carcinogenic potential.

studies,[7] was in an acceptable range, according to NIOSH, OSHA, and ACGIH standards or recommendations. However, during these studies, when a carcinogenic compound was used in the press cleaning solutions, its airborne concentration typically exceeded the action level, but less frequently exceeded the established limits for an 8-hour TWA PEL. Methylene chloride was a commonly found component of the cleaning solutions, and usually caused exposures above the action level when present. Benzene, when present, usually appeared as a contaminant below a concentration of 0.1 percent in the solution, the level at which potential carcinogens must be reported on the Material Safety Data Sheet (MSDS) for the solution. The resulting concentrations of benzene were high enough to be detected, resulting in a NIOSH recommendation to minimize exposures. Perchloroethylene was used relatively infrequently in press cleaning solutions.

The majority of measurements that we have made of the concentration of cleaning solution vapors at small lithographic printers (5 out of 6 sites) have either exceeded 50 percent of the PEL established for additive exposures, or involved a potentially carcinogenic component, or both. Although this sample is a tiny fraction of the estimated 50,000 small lithographic printing establishments, general observations at other sites suggest that these conditions may be common.

CONTROL PRINCIPLES

Before settling on local exhaust ventilation, other engineering measures were considered, including material substitution or equipment modification, and isolation or automation. An examination of the application of some of these measures in the small printing environment reveals several obstacles. For example, automation of the cleaning operation is expensive and beyond the means of these businesses. Although substitution of alternative cleaning solutions (vegetable oil- or water-based, with various additives) is effective in many cases in reducing airborne exposures, these alternative cleaning solutions tend to be more difficult to use and less effective cleaning agents than traditional products.[8,9] Many of these substitute solutions still have a substantial volatile organic component, as well as adverse health effects, which are sometimes worse than those associated with the original solution. Also, longer exposures to the vapors are necessary because of their reduced cleaning efficiency, which increases the potential for harmful effects. The development of the substitution approach has been driven largely by regulatory pressure from the Environmental Protection Agency (EPA).[10] As a remedy for reducing worker exposures, local exhaust ventilation can be relatively inexpensive and has a history of effectively controlling similar processes, therefore reducing the need to modify the process itself.

STUDY DESCRIPTION

Printing Facility

The study site was formerly a restaurant. The dining area had been converted to reception/office/photocopying functions. The original kitchen became the press area, with three sheet fed, offset lithographic presses in operation, two small two-color and one single-color press. The press area and the reception area each had its own HVAC (heating, ventilation, and air-conditioning) system. Neither system was modified during our study. Swinging doors connected the two areas. The press area occupied 1184 ft^2, and had a volume of 10,700 ft^3. There was no local exhaust ventilation at the start of our study.

Controls

Between our visits, two fresh air supply systems were installed in the printing facility to control airborne cleaning solvent vapors and anti-offset powder. One supplied the reception/copy and office areas, and the other the press area. The fresh air system in the press room provided local exhaust inlets to two of the three presses, as shown for one press in Figure 2. The press room system exhausted a total of 870 cfm from the two local exhaust inlets, while supplying 940 cfm of fresh air to four ceiling outlets (Figure 3). An air-to-air heat exchanger was installed in the fresh air systems (Figure 4) for energy economy. Figure 4 is a diagram of the airflow for the press room fresh air system.

Methods

Observations of airflow patterns were made using smoke tubes.

Real-time vapor concentration data was collected with a Brüel & Kjær Multi-gas Monitor Type 1302 (Brüel & Kjær, Gas Products Division, Nærum, Denmark), which has a photoacoustic detector. The inlet was located at a height of 1.5 m (60 inches) above the floor, and at the approximate mid point among the three presses. The quantity of TOC (total organic compounds) indicated by the multi-gas monitor is related to the sum of the concentrations of organic compounds. The instrument does not distinguish between two or more compounds which might have very different health effects. The sensitivity of the instrument varies for each compound. Therefore, because the indicated TOC level was a response to the combined concentration of organic compounds in unknown proportions, the indicated concentration cannot be compared to any health standards, but was most useful as a relative indicator of TOC concentration. The instrument was also used to sample simultaneously for CO_2 and H_2O vapor.

Real-time monitoring of the relative dust concentration was conducted before and after installation of the fresh air system, using a DataRAM (MIE, Inc., Billerica, Massachusetts) with an omni-directional sampling inlet located 1.5 m (60 inches) above the floor and adjacent to the presses. The DataRAM measures the intensity of light scattered from an illuminated volume, which depends upon the concentration of aerosol in the volume. It gives a maximum response to particles having a diameter between 0.1 and 10 μm.

Based on the listings of solution composition found on MSDSs and preliminary qualitative sample analysis by gas chromatography-mass spectrometry, full-shift, time-weighted-average personal and area sampling was carried out with charcoal

FIGURE 2
Photograph of local exhaust ventilation attached to the delivery end of a printing press.

tubes for isopropanol, methylene chloride, acetone, and total hydrocarbon (as n-hexane) vapors for two days before and after the fresh air systems were installed. The sampling rate was approximately 10 cm^3/min on August 10 and 11, and approximately 25 cm^3/min on September 14 and 15. Gas chromatography analysis of the charcoal tubes was conducted, using procedures specified in the NIOSH Manual of Analytical Methods,[11] 1400, 1005, 1300, and 1550, respectively. The sampling train contained one charcoal tube with a 100-mg front section and a 50-mg backup section.

RESULTS

Airflow Patterns

After installation of the fresh air system in the press area, investigators determined the airflow patterns around the two presses having the local exhaust inlets by using smoke tubes. With the presses operating, smoke released near the roller trains and from the paper delivery area traveled to the exhaust inlet, so solvent vapors and anti-offset powder should also be captured by the local exhaust system. Smoke release showed that there was a slightly lower pressure in the press room, resulting in a slight flow of air from the reception/copy area through the two connecting swinging doors into the press room.

Real-Time Vapor and Dust Concentrations

Figures 5 and 6 show the time dependence of the TOC and CO_2 concentrations in the press room. Both were relatively high during the day, when people were in the building and printing was in progress, and relatively low at night. As a result of the installation of the fresh air system, the real-time data shows that there was an 83 percent decrease in the average daytime level of TOC, and a reduction of above-background CO_2 of 82 percent in the press room.

The relative dust concentration data are shown in Figures 7 and 8. Peak dust concentrations before installation of the fresh air system were near 0.8 mg/m^3, and the TWA concentration was 0.22 mg/m^3 during working hours. After installation, the relative dust concentration peaked at 0.4 mg/m^3, and had a TWA of about

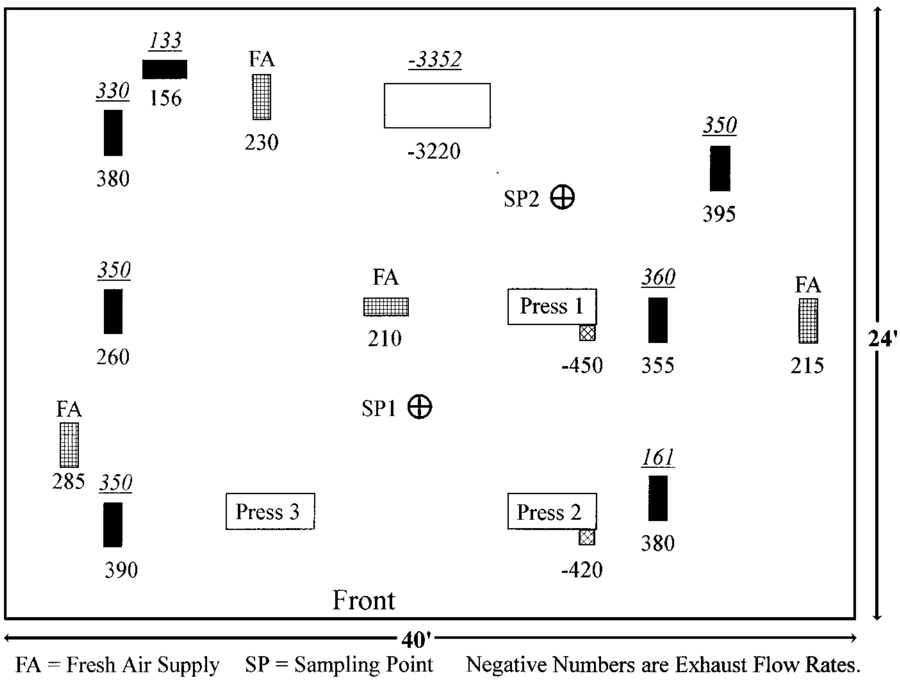

FIGURE 3
Press area: Sampling points and ventilation rates, cfm.

0.07 mg/m^3. The percent reduction in dust concentration was approximately 67 percent.

Solvent Usage

Cleaning solvents were applied from one-quart-capacity squeeze bottles. Investigators determined solvent usage by measurement of the level of the liquid in the bottles. However, these usage measurements were taken only on the two days after control installation. On September 14, the total solvent usage volume was 1.42 liters, and on September 15, it was 1.14 liters, 79 percent of the previous day's usage. The solvent usage volume was taken as a measure of the active production time.

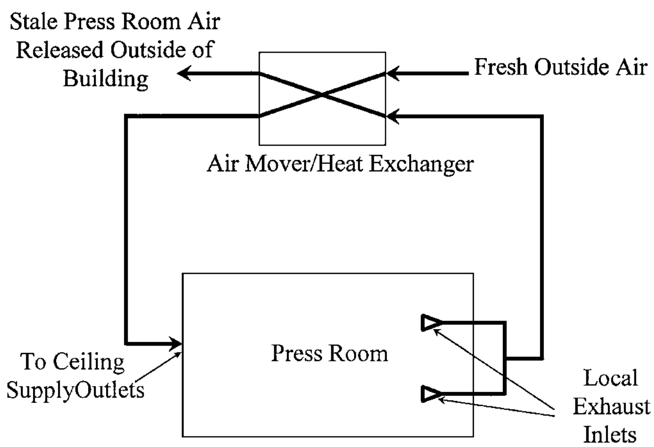

FIGURE 4
Fresh air supply system flow diagram.

Charcoal Tube Data

The charcoal tube sampling results are given in Table II. The concentrations for acetone were below the limit of detection (< 0.2 ppm), and not included in the tables or figures. Some of the methylene chloride and other hydrocarbon analyses indicated more than 30 percent of the sample was collected on the backup section, indicating possible loss of sample. These cases are indicated in Table II and should be considered lower limits for the actual concentration.

Employees are exposed to several solvent vapors simultaneously, and these vapors have some adverse (narcotic) health effects in common. Therefore, additive exposure levels were calculated and are shown in bar charts (Figure 9), along with levels for the individual species. For purposes of estimating additive exposures only, the OSHA 15-minute STEL (short-term exposure limit) of 125 ppm for methylene chloride was used. For all other substances, the OSHA 8-hour TWA PEL was used.

The horizontal bar chart of additive exposures (Figure 9) shows that before the fresh air supply was added, all three of the personal exposure samples for the press operators were about 37–45 percent of the additive PEL (3 components). After the addition of a fresh air supply, exposures were 8–18 percent of the additive PEL.

Because of the uncertain reliability of the methylene chloride data due to potential sample loss during initial sampling, a comparison between additive concentrations before and after

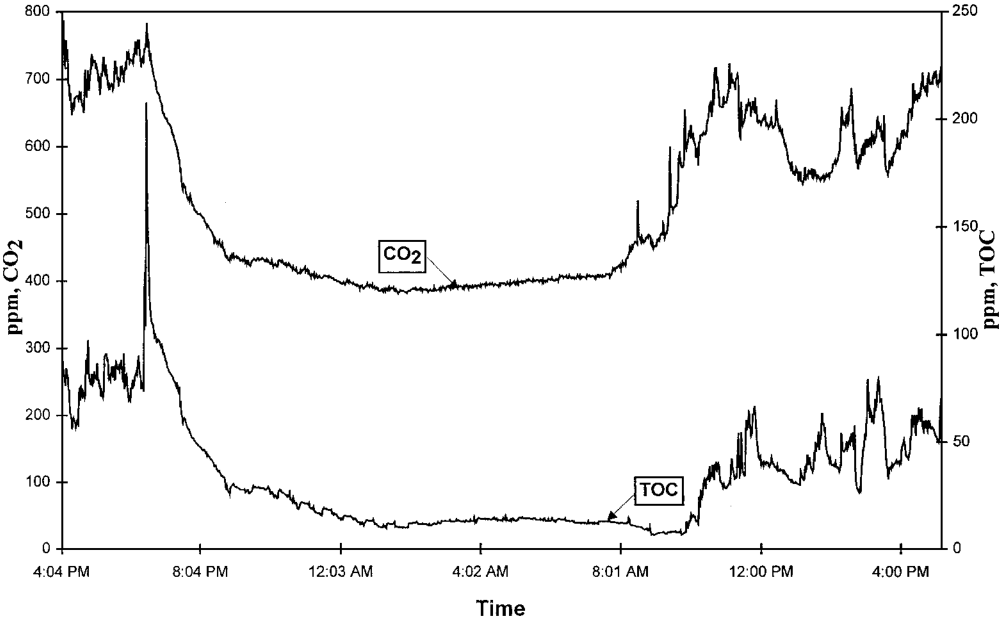

FIGURE 5
Concentration vs. time, B & K data, August 10, 11, 1995.

control introduction was made, based solely on the isopropanol and other hydrocarbon data. Using this reduced data set, the average percent reduction in additive two-solvent concentration for the press operators was 73 +/- 14 percent (95 percent confidence limit). Using the two sampling points in the area of the presses, the additive two-solvent concentration decreased by 86 +/- 10 percent.

After installation of the fresh air system, the average concentration of methylene chloride as measured by personal sampling of the press operators decreased by 44 +/- 30 percent, from 0.33 to 0.18 times the PEL. For the press area samples, the average methylene chloride concentration decreased by 73 +/- 26 percent, from 0.23 to 0.060 times the PEL, as a result of the addition of fresh air. The OSHA action level for methylene

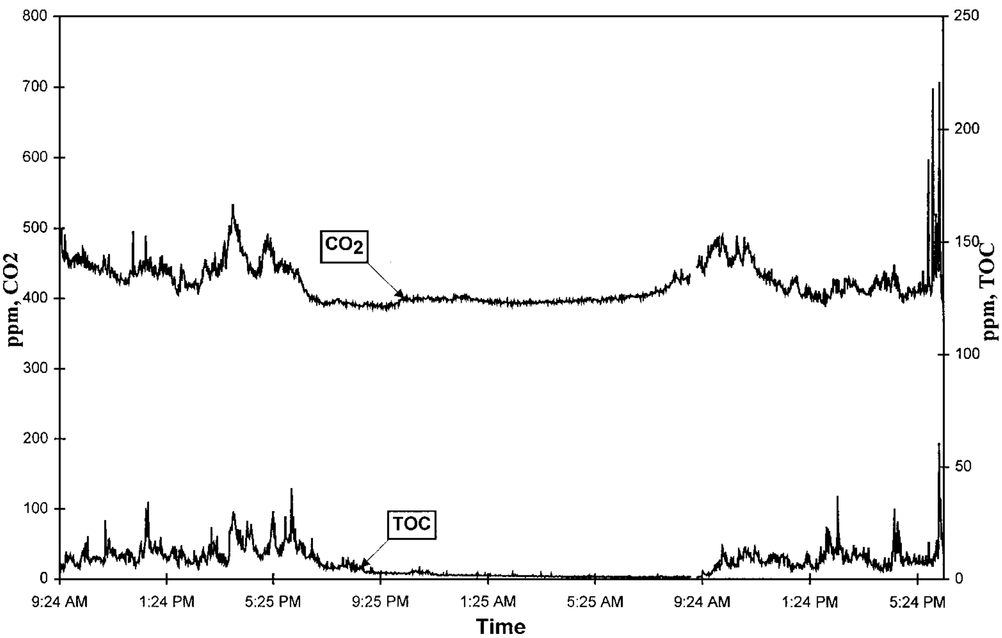

FIGURE 6
Concentration vs. time, B & K data, September 14, 15, 1995.

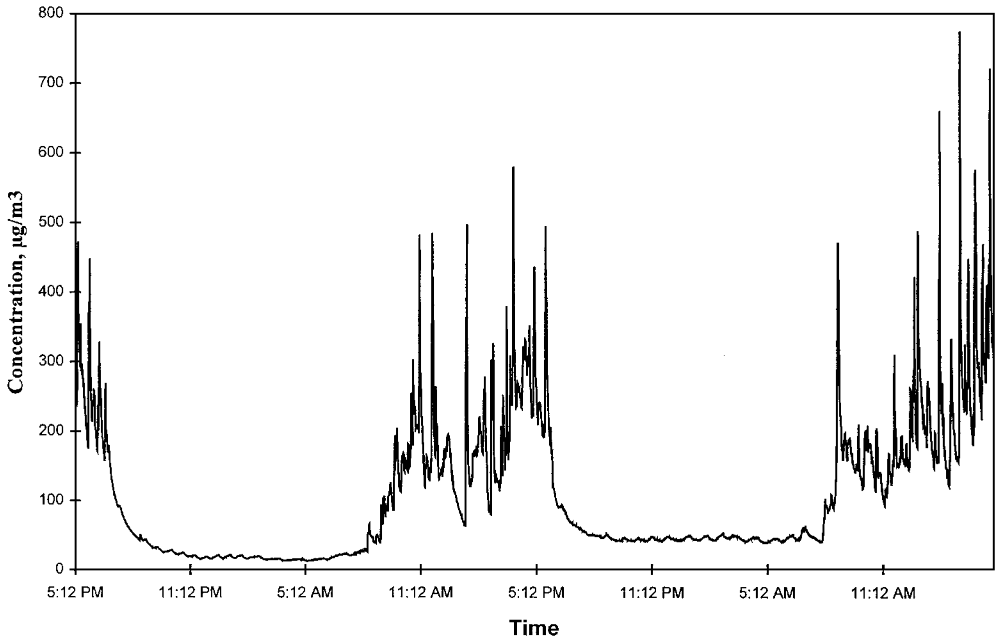

FIGURE 7
Concentration vs. time, DataRAM, August 9, 11, 1995.

chloride is 12.5 ppm. Table II shows that before installation of the fresh air system, no samples were at or above the action level, although the personal samples were near it. After installation of the fresh air system, the personal sample concentrations decreased to about half of the action level.

Because press operator C's press was not equipped with local exhaust ventilation (LEV), his exposure levels were compared to A's and B's by ANOVA, using the data in Table II, to see if it made a difference. For each of the analytes (isopropanol, methylene chloride, and other hydrocarbons), the ratio of C's personal sampling concentration to the mean of A's and B's was calculated for the four days. Before LEV was installed, the average of these ratios was 1.165 ($N = 6$). After LEV installation, the ratio was 1.453 ($N = 6$). Thus, A's and B's mean exposure levels

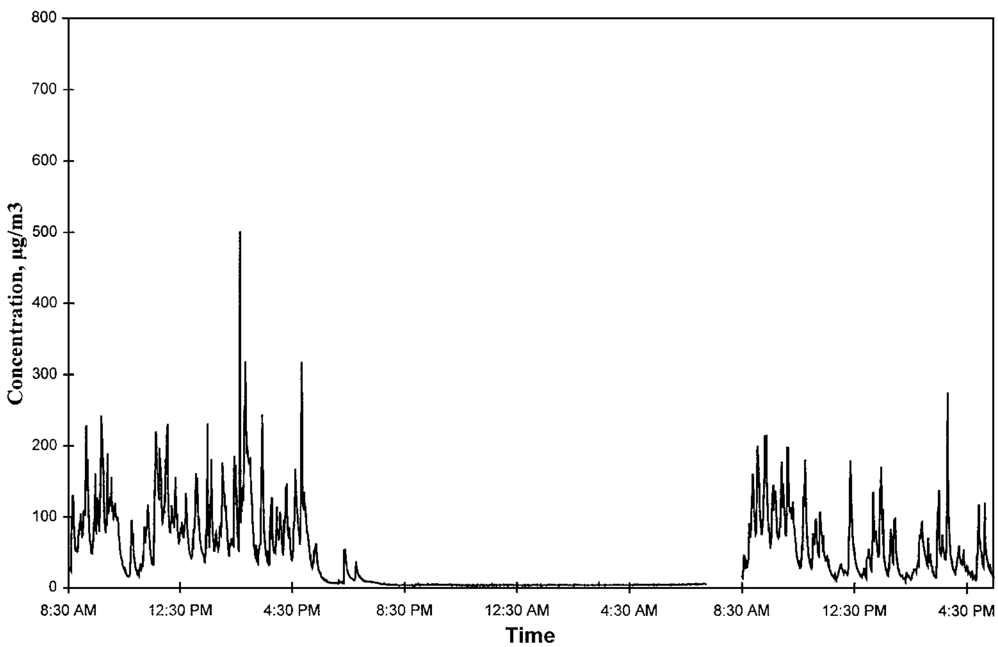

FIGURE 8
Concentration vs. time, DataRAM, September 14, 15, 1995.

TABLE II

Charcoal tube sampling results, 8-hour TWA concentration in ppm

Data worker/area	Isopropanol[A]				Methylene chloride[B]				Other hydrocarbons[C]			
	10 Aug	11 Aug	14 Sep	15 Sep	10 Aug	11 Aug	14 Sep	15 Sep	10 Aug	11 Aug	14 Sep	15 Sep
Customer service A	7	9	< 0.3	< 0.3	2	2	< 0.2	< 0.2	9	8	1[D]	1[D]
Press op A	34	37	8	10	9	8	4	3	29	24	4	3
Press op B	29	40	12	7	6	7	5	5	25	22	5	4
Press op C	35	45	20	10	11	9	7	4	27	24	7	5
Customer service B	8	9	1[D]	0[D]	2	1	0[D]	< 0.2	10	8	1[D]	1[D]
Photocopy	7	5	< 0.3	< 0.3	2	1	< 0.2	< 0.2	7	7	1[D]	1[D]
Reception	6	5	< 0.3	< 0.3	2	1	< 0.2	< 0.2	6	7	1[D]	1[D]
Office	7	5	< 0.3	< 0.3	2	1	< 0.2	< 0.2	6	7	1	1[D]
Press, central	30	40	7	6	6	5	2	2	19	23	3	3
Press, edge	24	38	4	2	6	5	1	1	19	22	2	1
Outdoors	< 0.3	< 0.3	< 0.3	< 0.3	< 0.2	< 0.2	< 0.2	< 0.2	2	3	1[D]	1[D]
PEL	400				25				100[C]			
TLV®	400				50				100[C]			
REL*	400				Lowest feasible				100[C]			

*NIOSH Recommended Exposure Limit.

[A]For isopropanol, the minimum detectable concentration (MDC) = 0.3 ppm and the minimum quantifiable concentration (MQC) = 1 ppm.

[B]For methylene chloride, the MDC = 0.2 ppm and the MQC = 0.5 ppm.

[C]For other hydrocarbons, the MDC = 0.3 ppm and the MQC = 1 ppm. The total hydrocarbons analysis was the sum of all peaks in the chromatogram minus the solvent peaks and all other named analyte peaks, quantitated against standards of n-hexane. The estimated limit(100 ppm) is based on an average value for similar chemicals. There has been no PEL, TLV, or REL established for this mixture.

[D]These quantities are between the MDC and the MQC.

Underlined quantities indicate that less than 30 percent of the sample was collected on the backup section, signifying possible loss of sample. These cases should be considered lower limits for the actual concentration.

Double underlined quantities indicate loss of the backup section during analysis; see discussion in text.

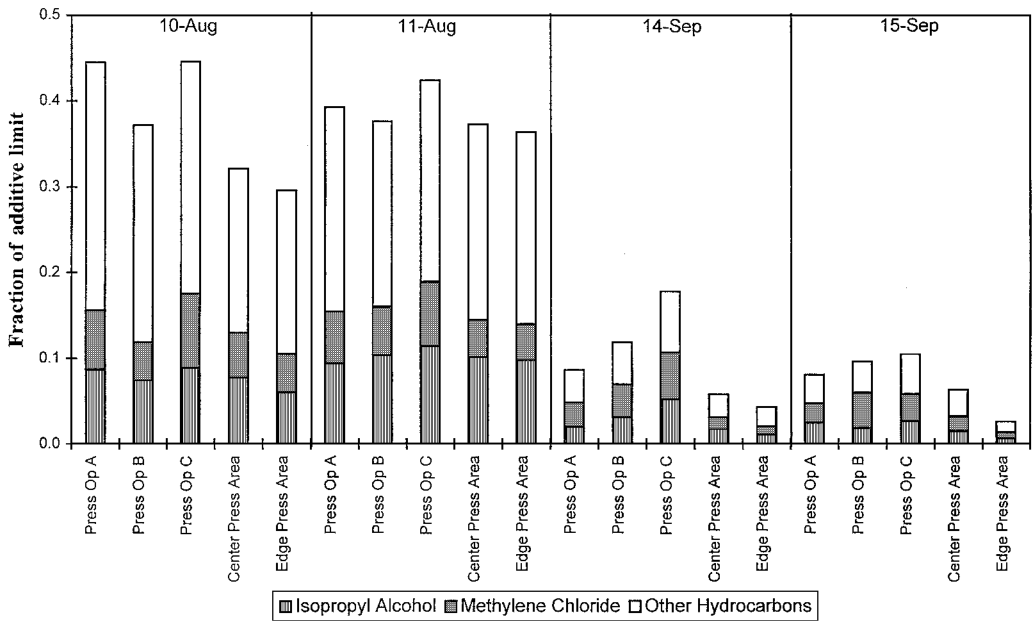

FIGURE 9

8-Hour TWA concentration relative to the estimated additive limit, personal and area samples.

improved relative to C's by 25 percent as a result of LEV installation on their presses. This difference is statistically significant at the 10 percent level.

DISCUSSION

There is no theoretical model to predict capture efficiency for a hood connected to an operating press. It is also not clear where a capture velocity should be measured, for comparison to a recommended velocity. Therefore, capture velocities were not measured. Instead, capture effectiveness was evaluated qualitatively by smoke release. The smoke tube results showed that apparently, any airborne material released near the working parts of the press (the roller trains for the ink and fountain solution, as well as the plate and blanket cylinders) was captured by the local exhaust system attached to the press. This expectation was confirmed by the real-time vapor and dust measurements, which showed reductions of 83 percent and 67 percent, respectively. The charcoal tube data also showed reductions in additive exposures (isopropanol + other hydrocarbons) of 73 percent for the press operators and 86 percent in the press area, in general agreement with the above results. Originally, in terms of health effects, the press operators' additive exposures (three components) were near, but below, 50 percent of the estimated additive limit. After installation of the controls, the additive exposures were less than 25 percent of the limit.

Figure 2 shows that the sides of the press served effectively as a flange on the bottom and one side of the hood. When a temporary flange (1-1/2 ft. high × 1 ft. wide) was added to the other side of the hood opening, smoke release showed that the area of hood influence was extended to about 6 inches beyond the side of the press opposite the hood, indicating that a lower exhaust rate could be used if the flange could be tolerated. No airborne solvent or dust measurements were taken with the temporary flange in place.

For a local exhaust hood external to the press, the location chosen here appears to be as close as feasible to the sources of emission. An alternative approach considered but not tried was to attach an exhaust duct to an opening cut in a side panel of the press. Potential benefits of this approach are that the exhaust system would permit complete access to normal operations of the press and that the exhaust flow would be well baffled by the external panels of the press. A drawback is that airborne dust would be pulled in to the press, increasing (perhaps minimally) the frequency of required press cleaning.

In view of the substantial reductions in the concentration of all other solvent vapors as a result of the addition of the fresh air system, it is surprising that the methylene chloride concentration for the press operators did not appear to decrease as much (44 percent versus 73 percent). The most likely explanation is that significant loss of the methylene chloride samples occurred during the August sampling period. This possibility is supported by the presence of less than 30 percent of the sample on the backup sampling tube in four of the six personal samples for methylene chloride in August (Table II). A similar loss of sample did not occur in September.

The average additive concentration (3 components) of the airborne solvent vapors determined by personal sampling of the press operators on September 15 was 73 percent of the concentration on September 14. The total solvent usage on September 15 was 79 percent of the previous day's usage, agreeing well with the additive exposure levels. If this agreement were not present, our assumption that the fresh air system was the primary cause of reduction of airborne solvent concentrations would be questionable. There would likely have been some other significant and unaccounted for source of variability. In addition, the average number of press operators at work during the airborne vapor sampling period on September 14 was 2.49, and on September 15 it was 2.07, 83 percent of the previous day's average number of workers. This lends some support to an assumption that the solvent usage rate is proportional to the number of press operators at work or the effective production time, because the solvent usage rate was reduced to about the same percentage (73 percent). Before control installation on August 10, the average number of press operators was 2.63, and on August 11, it was 2.34. Thus, there were on the average 8 percent fewer workers during the sampling periods after the control was installed than there were before, which could account for about 8 percent of the decrease in airborne vapor levels.

The anti-offset dust concentration was also reduced by 50–67 percent. Although high airborne concentrations of potato starch dust (> 30 g/m^3, the lower explosive limit [LEL]) are an explosion hazard, a literature search revealed no such occurrences in printing establishments as a result of dispersion of anti-offset dust. The concentrations of dust that we measured are more than four orders of magnitude below the LEL. Likewise, a slight fire hazard could arise from the settled dust, although, again, there was none evident in the literature. Also, a reduction of the concentration of airborne anti-offset powder reduces the likelihood of the development of allergic sensitization, leading to asthma. The presence of anti-offset powder in the exhaust air impacts maintenance considerations, and, thus, the long-term effectiveness of the system, covered in the recommendations.

RECOMMENDATIONS

For printing establishments where automation or substitution is not feasible, the application of local exhaust controls to offset lithographic presses appears to be an excellent control approach to reducing airborne cleaning solvent and anti-offset powder emissions, and should lead to acceptable worker exposures when used with complimentary control measures, such as wearing impermeable gloves and avoiding potentially carcinogenic solvents. The cost of the system installed in the press area for this study was about $15,000, which included the air-to-air heat exchanger. The payback time for the heat exchanger varies considerably with local conditions.[12] In a milder climate, a simpler system should be practical.

If effective substitutes can be found, solvents that contain methylene chloride should be replaced by ones that do not. Printers should be sure that the replacement solvents contain no potentially carcinogenic or otherwise highly toxic components (benzene, for example).

After control installation, press operator C had 50 percent higher exposures than the other operators, on average. Because operator C's press was the one without a local exhaust inlet, it would therefore appear prudent to equip all operating presses with a local exhaust takeoff.

The following suggestions affect the maintenance and efficiency of the ventilation control systems discussed previously. The ductwork should be smooth on the inside and have a circular cross-section. This will minimize dust accumulation in the ductwork and resistance to airflow. Also, a round, smooth duct will withstand greater negative pressures and support a larger buildup of dirt inside the duct. It can be cleaned, in contrast to most flexible, corrugated, or rectangular ducts. The duct should be sized to maintain at least 3000 feet per minute air velocity in the duct to prevent settling and accumulation of the anti-offset powder inside horizontal duct runs.[13] Assuming a 420-cfm exhaust flow as measured on Press 2, the associated branch of the ductwork should be 4 inches × 5 inches if rectangular, and 5 inches in diameter if round, to maintain the above mentioned minimum air velocity. There should be a dust filter at the inlet to the fresh air system to protect the air-to-air heat exchanger from degradation caused by dust accumulation. An electrostatic precipitator at this point might be an effective substitute and would have less air resistance than a filter. If not removed before it enters the fresh air system, the anti-offset powder can build up quickly in the fine passages of the heat exchanger, resulting in a need for frequent maintenance.

DISCLAIMER

Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention (CDC).

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