HETA 94–0293–2559
Fanelli Boys and Associates
Parkersburg, West Virginia

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Preface

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Acknowledgments and Availability of Report

This report was prepared by Michelle Canham, Greg Kullman, and Elizabeth Knutti, of the Respiratory Disease Hazard Evaluations and Technical Assistance Program, Clinical Investigations Branch, Division of Respiratory Disease Studies. Desktop publishing by Patricia Lovell.

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Health Hazard Evaluation Report 94–0293–2559
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February 1996

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SUMMARY

In June 1994, the National Institute for Occupational Safety and Health (NIOSH) received a confidential health hazard evaluation (HHE) request to evaluate exposures to laser printer toner among individuals employed at Fanelli Boys and Associates in Parkersburg, West Virginia. Health concerns expressed in the request included chest pain, eye irritation, skin rash, nasal problems, and deposits of black dust in the nose and mouth. An initial site visit was completed on July 6, 1994. On July 20-21, 1994, a combined medical and environmental evaluation was conducted at this worksite. The medical evaluation consisted of spirometry and a health questionnaire. Environmental evaluations included sampling for airborne dusts and organic vapors from toner recycling and ribbon or cartridge re-inking processes. Thermal decomposition products from melting holes in toner cartridges were also sampled.

The toners were comprised predominantly of a styrene-acrylate polymer and carbon black. Total dust concentrations from area and personal samples ranged from 0.07 milligrams per cubic meter of air (mg/m^3) to a high of 1.06 mg/m^3. Respirable dust concentrations from area samples ranged from below quantifiable limits (approximately 0.01 mg/m^3) to a high of 0.1 mg/m^3. None of these concentrations exceeded current personal exposure limits for particulates not otherwise regulated or classified (PNOC) as enforced by the Occupational Safety and Health Administration (OSHA) or recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). Although, certain work activities such as clean-up and filling toner cartridges outside the exhaust ventilation hood created increased potential for toner dust exposure. Volatile organic compounds measured at quantifiable concentrations in plant air included isopropanol, toluene, and 1,1,1- trichloroethane (1,1,1-TCE). Concentrations of these organic compounds were well below existing occupational exposure standards and criteria of OSHA, NIOSH, and ACGIH. Formaldehyde, possibly present as a thermal decomposition product from melting holes in toner cartridges, was quantified at concentrations of approximately 0.5 ppm; although, a potential for positive interference from styrene existed. The short term area formaldehyde concentrations exceeded occupational exposure criteria of both NIOSH (lowest feasible limit) and ACGIH (0.3 ppm as a ceiling concentration).

Five people (including the owner) work at this facility, and all five of the workers participated in the medical survey. Of the five, one showed an obstructive pattern and another had a mild restrictive disease pattern on pulmonary function testing. At least one of these individuals was aware of a preexisting respiratory disease; the other reported good health prior to this job. One worker reported symptoms felt to be work-related (eye irritation, rash on the arms, cough, and shortness of breath).

Based on the data collected during this survey, NIOSH investigators determined that a potential hazard existed from exposure to thermal decomposition products related to melting holes in toner cartridges. Recommendations for reducing exposures to dusts and solvents from cartridge recycling and ribbon inking are presented in this report.

Keywords: SIC 3861 (Photographic Equipment and Supplies), Toner, Styrene-acrylate Polymer, Re-inking, PNOC, Solvents, Recycling, Formaldehyde.

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INTRODUCTION

On June 10, 1994, NIOSH received a confidential health hazard evaluation (HHE) request to evaluate exposures to laser printer toner among individuals employed at Fanelli Boys and Associates, Parkersburg, West Virginia. Fanelli Boys and Associates specializes in recycling laser printer toner cartridges and printer ribbons. The health concerns that were expressed in the request included chest pain, eye irritation, skin rash, nasal problems, and deposits of black dust in the nose and mouth. After the initial site visit on July 6, 1994, concerns were also raised about exposures to organic vapors emitted from the use of an electric hot wire to burn holes into certain plastic toner cartridges and from the inks used to re-ink the printer ribbons. On July 20-21, 1994, combined medical and environmental evaluations were conducted at this worksite.

BACKGROUND

Laser printers, fax machines, and photocopiers have become commonplace in offices today. An essential component of these machines is the toner cartridge which contains the printing mechanisms and powdered black toner needed to produce printouts and photocopies. In 1991, greater than 15.2 million toner cartridges were used in the United States. Of these, 70 to 80 percent were discarded. The toner cartridge recycling and ribbon re-inking industry is part of an office supply recycling industry which emerged in response to environmental concerns about the increasing amounts of office waste.[(1)] The industry developed in the mid-1980's and has grown to include more than 4,000 small businesses. Between 1990 and 1992, the market for recycled toner cartridges grew by 133 percent. The number of recycled cartridges jumped from 0.78 million in 1990 to 4.23 million in 1992.[(2)]

Fanelli Boys and Associates, located in Parkersburg, West Virginia, is a small company in the office supply recycling industry. The company re-inks ribbons and cartridges for dot-matrix and ink-jet printers and recycles toner cartridges for laser printers. The company employs four individuals, two of whom are drivers and are present in the building only for a short time in the morning and late afternoon after deliveries are made. The other two employees work in the building where one spends the majority of his time cleaning and refilling the used toner cartridges. This employee is also responsible for some clean-up duties and can be sent on deliveries. The fourth currently employed worker is responsible for managing the ribbon re-inking process. This is the only employee that re-inks ribbons. The owner assists with refilling toner cartridges when necessary. Recently, another employee, who had also been cleaning and refilling toner cartridges, quit due to health concerns.

The Fanelli Boys and Associates building is constructed of cinder block with one main entrance and no windows other than two at the front of the building. Offices are located in the front half of the building. An eating area leads from the main office at the front of the building into a large, open, back room which comprises the entire back half of the building. The section of the back room nearest the eating area is designated as the re-inking area where the re-inking supplies and equipment are kept and used. The toner cartridge recycling area is located on the opposite side of this room, partially separated from the re-inking area by a plastic sheet. The unopened bottles of toner are shelved on this side of the room and all supplies used when cleaning the cartridges are stored at the two work benches in this area. This room also contains printers used to test the recycled cartridges and storage for additional supplies. There is a garage door and one emergency exit in this back room. These doors remain closed, as the building is air conditioned. The toner cartridge recycling process is similar for each cartridge type that is recycled. It involves disassembling the cartridge, removing the internal components, emptying the cartridge of used toner, refilling it with new toner, and reassembly. The disassembling and assembling is done at the work bench. Toner left in the cartridges is removed under an exhaust ventilation hood. Toner is refilled over a wastebasket outside the hood. In order to refill cartridges with inaccessible toner hoppers, a hot electric wire is used to burn a hole into the side of the cartridge. Lubricants are applied to the movable parts of the cartridge. The worker wears latex gloves, but does not wear respiratory protection.

The re-inking process for dot matrix printer ribbons involves positioning used ribbons on small machines that rotate the ribbons slowly, uniformly distributing ink from an ink reservoir onto the ribbons. The worker monitors the machines when they are in use, refilling the ink reservoirs as needed. Most re-inking processes require little contact with the ribbon and ink except to refill the ink reservoirs. However, some re-inking processes require more handling. For example, some dot matrix printers have very large spools of ribbon which must be wound tightly after being re-inked. This requires that the worker apply pressure to the re-inked spool as it is being rewound. Latex gloves and an apron are worn and paper towels are used to reduce skin contact with the ink.

METHODS

Environmental

The environmental evaluation took place on July 20 and 21, 1994, from approximately 8:00 a.m. until 5:00 p.m., the company business hours. Area samples were taken from six locations throughout the building. Samples were collected for total dust, respirable dust, particle size distribution, and organic compounds. Personal breathing zone samples were taken on two employees. Total dust and organic compound samples were collected from the employee who refills the toner cartridges. An organic compound sample was collected from the employee who re-inks ribbons. Short-term samples were collected for carbon monoxide, ammonia, hydrochloric acid, and formaldehyde during the burning of the plastic toner cartridges. Carbon dioxide (CO_2) indicator tubes were used to evaluate the indoor and outdoor CO_2 concentrations as markers of indoor air quality. In addition, temperature and relative humidity measurements were obtained using an electronic humidity and temperature meter. The building's heating, ventilation, and air-conditioning (HVAC) system was also examined. Table 1 describes in more detail the sampling methods used during the survey.

Medical

All five workers (four employees and owner) were invited to participate in the medical portion of the study, which consisted of an interviewer-administered health questionnaire and pulmonary function testing.

Health Questionnaire

Questions concerning health, present and past work experiences, and smoking histories were included in the questionnaire. Chronic cough was defined as cough occurring on most days for as much as three months during the year. Chronic phlegm was similarly defined. Chronic shortness of breath was defined as shortness of breath while walking with other people of one's own age on level ground. Questions were also asked about chest tightness and wheezing or whistling noises in the chest. There were also questions about symptoms of an irritant nature and whether these were related to time spent at work. Individuals who currently smoke cigarettes were defined as current smokers. Individuals who have smoked five or more packs of cigarettes during their entire life, but do not currently use cigarettes, were classified as ex-smokers.

Spirometry

Spirometric examinations were performed according to American Thoracic Society Guildlines[5] employing a waterless rolling seal spirometer connected to a dedicated computer, which recorded the maneuvers. Each participant performed at least five forced expirations. The forced expired volume in one second (FEV_1) and forced vital capacity (FVC), converted to body temperature and ambient

Table 1
Environmental Sampling Methods
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Analyte	Sampler	Media	Air Sampling Rate	Sampling Time	Sample Analyses
Total dust	Total dust cassette	DM 800 copolymer filter (37mm)	2.0 liters per minute (lpm)	5-8 hours	Gravimetric[3]
Respirable dust	Respirable cyclone	DM 800 copolymer filter (37mm)	1.7 lpm	5-8 hours	Gravimetric[3]
Particle size distribution	Cascade impactor	Grease- coated mylar	2.0 lpm	5-8 hours	Gravimetric[3,4]
Organic compounds / Hydrocarbons	Solid sorbent tube	Activated charcoal	1.0 lpm and 50 cubic centimeters per minute	4-8 hours	Gas chromatography[3]
Gases: Ammonia Carbon dioxide Carbon monoxide Formaldehyde Hydrochloric acid	Direct reading indicator tubes	—	—	5 minutes	Colormetric: Length of stain in sample tube proportional to air concentration of contaminant. A direct measure.[4]

pressure saturated (BTPS) with water vapor, were recorded from each maneuver. The highest FEV_1 and FVC from the maneuvers were selected for analysis. Predicted values were calculated using the Knudson reference equations.[6] Test results were compared to the 95th percentile lower limit of normal (LLN) values obtained from Knudson's reference equations to identify participants with abnormal spirometry patterns of obstruction and restriction. By definition five percent of a normal, non-smoking population would be expected to have predicted values that fall below the LLN, while 95% will have predicted values above this value.

Using this comparison, obstructive and restrictive chronic airway disease patterns are defined as:

Obstruction: Observed ratio of FEV1/FVC% below the LLN.

Restriction: Observed FVC below the LLN and ratio at or above the LLN.

The criteria for interpretation of the level of severity for obstruction and restriction, as assessed by spirometry, are as follows:

	OBSTRUCTION (FEV1/FVC x 100)	RESTRICTION (% Predicted FVC)
Mild	>60,<LLN	>65, <LLN
Moderate	45 - 60	51 - 65
Severe	<45	<51

EVALUATION CRITERIA

Environmental

Evaluation criteria are guidelines commonly used by NIOSH investigators to assess the potential health effects of occupational exposures to substances and conditions found in the work environment. These criteria consist of exposure levels for substances and conditions to which most workers can be exposed day after day for a working lifetime without adverse health effects. Because of variation in individual susceptibility, a small percentage of workers may experience health problems or discomfort at exposure levels below these criteria. Consequently, it is important to understand that these evaluation criteria are guidelines for occupational exposures, not absolute limits between safe and dangerous levels of exposure.

Several sources of evaluation criteria exist and are commonly used by NIOSH investigators to assess occupational exposures. These include:

1. The U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) permissible exposure limits (PEL's);[7]

2. The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit (Exposure) Values (TLV's);[8]

3. NIOSH recommended exposure limits (REL's).[9]

These criteria have been derived from industrial experience, from human and animal studies, and when possible, from a combination of the three. Due to differences in scientific interpretation of these data, there is some variability in exposure recommendations for certain substances. Additionally, OSHA considers economic feasibility in establishing occupational exposure standards; NIOSH and ACGIH do not consider economic feasibility in development of their criteria.

The exposure criteria described in this report are: Time-weighted average (TWA) exposure recommendations averaged over the full work shift; short-term exposure limit (STEL) recommendations for a brief (10-15 minute) exposure period; and ceiling levels (C) not to be exceeded for any amount of time. These exposure criteria and standards are commonly reported as parts contaminant per million parts air (ppm), or milligrams of contaminant per cubic meter of air (mg/m^3). Occupational criteria for the air contaminants measured during this study are presented in Table 2.[7-9]

Table 2
Occupational Exposure Criteria
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Contaminant	NIOSH (REL)	ACGIH (TLV)	OSHA (PEL)
Ammonia	25 ppm (TWA) 35 ppm (STEL)	25 ppm (TWA) 35 ppm (STEL)	50 ppm (TWA)
Carbon black	3.5 mg/m^3 (TWA)	3.5 mg/m^3 (TWA)	3.5 mg/m^3 (TWA)
Carbon dioxide	5000 ppm (TWA) 30,000 ppm (STEL)	5000 ppm (TWA) 30,000 ppm (STEL)	5000 ppm (TWA)
Carbon monoxide	35 ppm (TWA) 200 ppm (C)	25 ppm (TWA)	50 ppm (TWA)
Formaldehyde	0.016 ppm (TWA) 0.1 (STEL)	No TWA 0.3 ppm (C)	0.75 ppm (TWA) 2.0 ppm (STEL)
Hydrochloric acid	5 ppm (C)	5 ppm (C)	5 ppm (C)
Isopropanol	400 ppm (TWA) 500 ppm (STEL)	400 ppm (TWA) 500 ppm (STEL)	400 ppm (TWA)
Particulates not otherwise classified (PNOC)	No REL	10 mg/m^3 (TWA, inhalable) 3 mg/m^3 (TWA, resp.)	15 mg/m^3 (TWA, total dust) 5 mg/m^3 (TWA, respirable dust)
Toluene	100 (TWA) 150 ppm (STEL)	50 (TWA)	200 ppm (TWA), 300 ppm (C) 500 ppm (10-min. Peak)
1,1,1-TCE	350 ppm (C)	350 (TWA) 450 ppm (STEL)	350 (TWA)

TWA - Time-Weighted Average
STEL - Short-term Exposure Limit
(C) - Ceiling exposure limit.
ppm - parts per million parts air by volume
mg/m^3 - milligrams per cubic meter of air.

RESULTS

Environmental

Total dust concentrations in air are presented in Table 3; both personal and area samples were collected. Concentrations are presented by sampling location in milligrams of dust per cubic meter of air (mg/m^3). Concentrations from the 10 area samples ranged from 0.03 mg/m^3 to a high of 0.40 mg/m^3. The two personal exposure measurements for total dust were 0.33 mg/m^3 and 1.06 mg/m^3. These personal samples were collected from the employee who recycled cartridges in the work bench area. The highest total dust concentrations from both personal and area samples were measured in the work bench area where most of the cartridge recycling activities were done. The office and ink bench areas had lower dust concentrations. The highest personal exposure measurement was taken on the day when the employee cleaned the work bench area using pressurized air. None of the personal or area samples exceeded the exposure limits for particulates not otherwise classified or regulated (PNOCs). The OSHA PEL for total PNOCs is 15 mg/m^3 as a TWA; the ACGIH TLV is 10 mg/m^3 for inhalable particulate also as a TWA. NIOSH has no REL for total PNOCs.(7-9)

Table 3
Total Dust Concentrations in Air
Concentrations in mg/m^3
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SAMPLE TYPE[1]	LOCATION	CONCENTRATION (mg/m^3)	
		July 20	July 21
AREA	VACUUM ROOM	0.23	0.07
AREA	WORK BENCH AREA	0.40	0.39
AREA	PRINTER AREA	0.07	0.10
AREA	OFFICE AREA	0.03	0.05
AREA	INK BENCH	0.07	0.03
PERSONAL	WORK BENCH AREA	0.33	1.06

[1] Personal, breathing zone or area samples
mg/m^3 - milligrams per cubic meter of air.

Respirable dust concentrations are presented in Table 4. The concentrations from the 10 area samples are presented by sampling location in mg/m^3. Concentrations ranged from below the minimum quantifiable concentration (MQC approximately 0.01 mg/m^3) to a high of 0.10 mg/m^3. The vacuum room and work bench areas had the highest respirable dust concentrations. None of the personal or area samples exceeded the exposure limits for respirable PNOCs. The OSHA PEL for respirable PNOCs is 5 mg/m^3 as a TWA; the ACGIH TLV is 3 mg/m^3 also as a TWA. NIOSH has no REL for respirable PNOCs.(7-9)

Table 4
Respirable Dust Concentrations in Air
Concentrations in mg/m^3
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SAMPLE TYPE[1]	LOCATION	CONCENTRATION (mg/m^3)	
		July 20	July 21
AREA	VACUUM ROOM	0.06	0.10
AREA	WORK BENCH AREA	0.05	0.07
AREA	PRINTER AREA	MQC	0.04
AREA	OFFICE AREA	0.04	0.04
AREA	INK BENCH	0.05	0.03

mg/m^3 - milligrams per cubic meter of air.
MQC - Below the minimum quantifiable concentration of approximately 0.01 mg/m^3.

Particle size distributions are presented by sampling location in Table 5. Only samples from the work bench and vacuum room areas had sufficient mass per stage for size distribution calculations; samples from other areas were voided due to insufficient mass on some impactor stages. Most of the mass of airborne particulate from the work bench area exceeded 10 micrometers (µm) in aerodynamic diameter and was not of respirable size; approximately 21 percent of the mass of airborne particulate from the work bench area was below 10 µm in aerodynamic diameter and in the respirable fraction. The sample had a mass median aerodynamic diameter (MMAD) of 17.4 µm with a geometric standard deviation (GSD) of approximately 1.5. The two airborne particulate samples from the vacuum room had a smaller collective size distribution with a combined MMAD of 10 µm and a GSD of approximately 1.6. A larger percentage of the mass (approximately 42 %) of airborne particulate from the vacuum room area was below 10 µm in aerodynamic diameter and in the respirable fraction.[10]

Table 5
Particle Size Distribution of Airborne Particulate by Sampling Location
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Sampling Location	Impactor Stage Number	Median Stage Cutoff Size for Particles (µm)	Cumulative Percent Mass Less than Particle Size
Work Bench Area	1	20	68.4
	2	15	42.1
	3	10	21.0
(1 Sample)	4	6	15.8
	5	3.5	10.5
	6	2	5.3
	Final	1	0
Vacuum Room Area	1	20	92.5
	2	15	72.5
	3	10	42.5
(2 Samples)	4	6	20.0
	5	3.5	5.0
	6	2	2.5
	Final	1	0

Volatile organic compounds were selected for quantification based on initial qualitative analysis of high volume air samples. Seven compounds were selected for quantification based on relative abundance in the high volume samples and by the potential hazard based on vapor pressure and toxicity. These organic compounds included isopropanol, 1,1,1-trichloroethane (1,1,1-TCE), methyl isobutyl ketone (MIBK), benzene, styrene, toluene, and n-hexane. Styrene and n-hexane were below detectable limits in all charcoal tube samples analyzed quantitatively; this corresponds to a minimum detectable concentration (MDC) of approximately 0.04 ppm for styrene and approximately 0.05 ppm for n-hexane. Concentrations of benzene and MIBK were all below the minimum quantifiable concentrations, approximately 0.17 ppm for benzene and 0.14 ppm for MIBK. Tables 6 and 7 contain the concentrations of isopropanol, toluene, and 1,1,1-TCE from area and personal samples.

Only 4 of the 16 toluene samples had concentrations above quantifiable limits (approximately 0.05 ppm based on the air volume sampled). Toluene concentrations in those samples above the LOQ ranged from 0.04 ppm to 0.06 ppm. The concentrations of toluene in both the personal and area samples were similar across the different sampling locations. The area concentrations and personal exposures measured for toluene during this survey were all well below the personal exposure standards enforced by OSHA and the exposure criteria recommended by ACGIH and NIOSH. The ACGIH TLV for toluene is 50 ppm as a TWA. The OSHA PEL for toluene is 200 ppm as a TWA. The NIOSH REL for toluene is 100 ppm as a TWA.[7-9]

Isopropanol was used to clean the toner cartridge. The inks used in the re-inking process are another potential source of the alcohol detected in these samples. All of the air samples had quantifiable concentrations of isopropanol; concentrations ranged from 7.1 ppm to a high of 23.5 ppm. The concentrations of isopropanol from the ink bench area were higher than those measured in other areas. The highest concentration of isopropanol was also measured in an area sample collected from the re-inking process, 20.1 ppm. Isopropanol concentrations were generally higher on the first day of sampling as contrasted to day two; although, there is no apparent explanation for this. The area concentrations and personal exposures measured for isopropanol during this survey were all below the personal exposure standards enforced by OSHA and the personal exposure criteria recommended by ACGIH and NIOSH (all 400 ppm as a TWA).

Trichloroethane was a constituent in the Teflon® dry film used to lubricate all movable parts before toner cartridge reassembly. All of the personal and area samples had quantifiable concentrations of 1,1,1-TCE; concentrations ranged from 0.09 ppm to a high of 1.51 ppm. The highest concentration was measured in an area sample from the work bench. The work bench area had the highest 1,1,1-TCE concentrations on both days of sampling; although any differences in concentration by area were small. The area concentrations and personal exposures measured for 1,1,1-TCE during this survey were allbelow the personal exposure standards enforced by OSHA and the personal exposure criteria recommended by ACGIH (350 ppm as a TWA) and NIOSH (350 ppm as a ceiling).[7-9]

Table 6
Organic Compounds From Area Air Samples
Concentrations in PPM
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SAMPLING LOCATION	DATE	CONCENTRATION IN PPM		
		Isopropanol	Toluene	1,1,1-TCE
Vacuum Room	July 20 July 21	17.3 8.11	(0.05) (0.05)	0.09 0.85
Work Bench	July 20 July 21	15.9 7.83	(0.03) 0.06	1.51 0.93
Printer Area	July 20 July 21	15.9 7.61	(0.04) (0.06)	1.19 0.78
Office	July 20 July 21	16.7 8.44	0.05 (0.04)	1.28 0.76
Ink Bench	July 20 July 21	23.5 9.15	0.04 (0.04)	1.21 0.76
Cartridge Melting Area	July 20 July 21	16.5 7.10	(0.05) (0.05)	1.31 0.86

( )-Indicates toluene air concentrations that were estimated based on laboratory values between the analytical limit of detection (LOD) and quantification (LOQ)
LOQ=4.0 micrograms per sample or approximately 0.05 ppm based on average sample air volume.

Table 7
Personal Exposures to Organic Compounds
Concentrations in PPM
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Worker Job/ Location	DATE	CONCENTRATION IN PPM		
		Isopropano l	Toluene	1,1,1-TCE
Refill Toner Cartridges – Work Bench	July 20 July 21	13.9 7.19	(0.04) (0.06)	1.26 0.88
Re–ink Printer Ribbons – Ink Bench	July 20 July 21	20.1 9.62	(0.04) 0.05	1.51 0.76

( )-Indicates toluene air concentrations that were estimated based on laboratory values between the analytical limit of detection (LOD) and quantification (LOQ)
LOQ=4.0 micrograms per sample or approximately 0.05 ppm based on average sample air volume.

Thermal Decomposition compounds produced by cartridge burning are presented in Table 8. Short-term samples for ammonia, carbon monoxide, and hydrochloric acid were all below detectable limits in the air samples. Formaldehyde was detected as a decomposition product from cartridge burning on both days of sampling at concentrations of 0.4 and 0.5 ppm. These formaldehyde samples were collected using short-term indicator tubes; styrene was listed as a potential interfering compound; consequently, it is possible that a portion of the positive formaldehyde reading is attributable to interference from styrene, although this cannot be resolved with this data. Both of these sample concentrations (discounting any potential interference) exceeded the NIOSH REL and ACGIH TLV (0.1 ppm as a STEL and 0.3 ppm as a ceiling respectively). The OSHA PEL for formaldehyde as a STEL is 2.0 ppm.[7-9]

Table 8
Air Contaminants Released By Cartridge Burning
Concentrations in PPM
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CONTAMINAN T	DATE	SAMPLE S	CONCENTRATIO N RANGE
Ammonia	July 20	1	ND (< 5 ppm)
Carbon Monoxide	July 20 July 21	1 2	ND (< 5 ppm) ND (< 5 ppm)
Formaldehyde	July 20 July 21	1 3	0.5 ppm ND(< 0.2 ppm) to 0.4 ppm
Hydrochloric Acid	July 20	1	ND (< 1 ppm)

Carbon dioxide (CO_2) concentrations in air are presented in Table 9; samples were collected from both indoor and outdoor locations during each day of sampling. Indoor concentrations exceeded outdoor concentrations on both days of sampling. The average outdoor CO_2 concentration during both days of sampling was 350 ppm as contrasted to an average indoor CO_2 concentration of 1350 ppm. These indoor concentrations are below the existing OSHA PEL, ACGIH TLV, and NIOSH REL for CO_2.[7-9] However, they are elevated in comparison to ambient CO_2 concentrations. The number of CO_2 samples collected during this survey was limited, but this data suggests that there is a potential for inadequate outside air intake or distribution to work areas.[11]

Table 9
Carbon Dioxide Concentrations in PPM
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LOCATION	CONCENTRATION (PPM)	
	July 20	July 21
Outdoors	500	200
Indoors	1700	1000

Building ventilation consisted of one main, 3-year-old heating, ventilating, and air-conditioning (HVAC) unit serving the entire building. There was no visible outside air intake for this HVAC. A second, 20-year-old air- conditioning unit was mounted to the ceiling in the back room. One floor fan was located near the re-inking work bench and another was located near the cartridge recycling area.

Two local exhaust ventilation systems were operated to control dust exposures in the work bench area. The exhaust hoods were built side-by-side into the wall adjacent to the work benches. Both hoods were partial enclosing hoods by design; the openings were located in the front part of the hood and both measure 7.5 inches high by 23 inches wide for a hood face area of approximately 1.2 square feet. Excess toner remaining in used toner cartridges was disposed of under the hood. The bulk of the toner left in used cartridges was emptied into a collection port inside the hood which leads to a sealed dump bucket. To the side of each of these hoods there was an air gun which provided compressed air used to clean out any toner remaining in the used cartridges. The hood which was used most often (Hood 1) runs continuously and pulls toner suspended under the hood through a prefilter, followed by a HEPA filter, and finally a charcoal filter. The prefilters rest at the back of the hood at the opening leading to the HEPA and charcoal filters. The prefilters are held in place at the back of the hood by an old filter box. Weatherstripping was used to try to seal the HEPA filter into place. There was no other seal on the filters.

The second hood (Hood 2) was operated intermittently using a foot pedal which, when depressed, activates two Sears shop vacuums. Toner emptied under this hood is collected in these vacuums. The vacuums for the second hood and the filter system for the first hood were located in a small, enclosed room behind the hoods (the vacuum room).

Air flow measurements taken during the first day of the survey with a hot wire anemometer indicated that Hood 1 operated at a flow rate of 203 cubic feet per minute (cfm). The average air velocity at the hood face was 169 feet per minute (fpm). Hood 2, operated intermittently, had a volumetric flow rate of 336 cfm with an average air velocity at the hood face of 280 fpm. Collectively, these data indicate that both hoods were operating with sufficient volumetric flow and air velocity to contain the dusts from cartridge dumping and most activities done within the hood; the enclosed hood design helped to contain airborne particulates at the air flow rates in use. Visual observation of work activities also served to confirm this. The local exhaust ventilation hoods were much less effective at containing dust for activities done outside the hood such as cartridge filling and cleaning bench surfaces with compressed air.[12]

Medical

All five workers completed a health questionnaire and performed spirometry. There were two males and three females, whose ages ranged from 29 to 44 years. One participant was a smoker, one a former smoker, and three reported to have never smoked cigarettes. Tenure for the five employees ranged from 4 to 60 months. When asked specifically about health problems thought to be a result of their work at Fanelli Boys, the following symptoms were mentioned: eye irritation, rash on the arms, cough, and shortness of breath. Two of the workers felt that their nasal irritation was the result of allergies and not related to work. Eye irritation was also mentioned in relation to hay fever, allergies, and season of the year, as well as work exposure. Of the two workers reporting chest tightness, one reported having asthma since childhood but felt that the asthma was not worsened by working at Fanelli Boys. The other noticed no set pattern for chest tightness and associated it with colds.

Baseline spirometry results for three of the five workers were within normal limits for their age, height, and sex. One worker showed a mild restrictive pattern and another had a moderate obstruction to airflow. The two with abnormal pulmonary function results also reported occasional shortness of breath. The individual with obstructed airflow also reported chest tightness, though there did not appear to be any consistent pattern for time or day of occurrence, or relationship to obvious factors, including work.

DISCUSSION

Environmental

Dust Exposures from Toner Cartridge Recycling

The recycling of toner cartridges for laser printers involves worker exposures to dusts through the removal of the residual toner, cartridge recycling steps, and through the addition of new toner. Toners currently on the market are predominantly a mixture of 85% styrene-acrylate polymer, 10% carbon blank, and 5% charge control agent.[13,14] Animal exposure studies involving rats show that toner exposures can result in impaired but reversible alveolar clearance, toner deposition in the lung, and mild fibrosis. Exposure to toner at high concentrations exceeding 40 mg/m^3 resulted in irreversible impairment of alveolar clearance, excessive deposition of toner in the lung tissue, and fibrosis. The respiratory effects observed at higher toner exposures are likely attributed to excessive lung particulate burden and lung overloading. Animal exposure studies also suggest that toners are not carcinogenic since formulations were developed with high purity carbon black.[14-19] Experimental results from one human inhalation study showed that brief exposures to toner dust concentrations at 2 mg/m^3, 10 mg/m^3, and 25 mg/m^3 did not affect mucocilliary clearance or lung function among study participants.[20] Bellman et al. suggest that toner can be categorized as a "nuisance dust" according to ACGIH criteria, also referred to as "particulates not otherwise classified" (PNOC).[16] The criteria for the classification of a substance as a PNOC would include the following characteristics: (1) the architecture of the air spaces remains intact; (2) collagen (scar tissue) is not formed to a significant extent; and (3) the tissue reaction is potentially reversible.[8]

Fourteen toner cartridges were recycled during the first day of sampling (July 20, 1994); nine cartridges were recycled on the following day of sampling. This was described to be approximately normal production for one worker at this worksite. Total dust concentrations measured during these two days of sampling were highest in the work bench area where the cartridge recycling was done; the average personal total dust exposures for the worker recycling toner cartridges was 0.70 mg/m^3. Both the personal and area total dust concentrations were well below the OSHA PEL for PNOC (15 mg/m^3 as a TWA) and the ACGIH TLV for PNOC (10 mg/m^3 as a TWA).[7-9] Respirable dust area concentrations were also well below the OSHA PEL for PNOC as a respirable dust (5 mg/m^3 as a TWA) as well as the ACGIH TLV (3 mg/m^3 as a TWA). The respiratory health effects from dust exposure depend both on the nature of the particulate, the regional site of lung deposition, and other physical and chemical dust properties.[10,21] Both the respirable dust data and particle size distribution results suggest that the majority of the particulate mass from the work bench area was nonrespirable with a MMAD of approximately 17 micrometers. This dust would be deposited largely in the upper respiratory tract and in conducting airways. Approximately 21 percent of the airborne particulate mass was below 10 µm and in the respirable fraction. Respirable dusts, called such due to their size characteristics and ability to penetrate to gas exchange regions of the lung, include particulates less than approximately 10 micrometers in aerodynamic diameter. Dusts in this size range are deposited in the alveoli and respiratory bronchioles and, depending on the dust characteristics, can cause pulmonary fibrosis.[10]

The area dust concentrations and personal dust exposures were measured with a local exhaust ventilation system in place to remove particulate from the cartridge recycling process. When used or leftover toner was cleaned from the cartridges, it was done under a hood. The hood appeared an effective control for the removal of this material and effective in reducing worker exposure to toner dust. However, not all work activities were done under the hood. The refilling of toner cartridges took place outside of the hood over a garbage can. An open toner bottle was fitted with a nozzle which could be placed into the unplugged end of a toner cartridge. The recycled cartridge was then refilled with toner outside of the hood creating increased potential for worker exposure to toner dusts.

Activities such as cleanup were also done without the use of local exhaust ventilation and this activity created the potential for increased dust exposures. The toner cartridge recycling area is cleaned every Thursday afternoon and this represents a potential high dust exposure activity. A shop vacuum was used to vacuum excess toner that had accumulated inside of the hood and on the hood prefilters. The prefilters were not replaced. To vacuum the prefilters, the worker was required to handle these filters outside of the hood. The filters had collected a large amount of toner which generated visible dust during the cleaning process. However, the dust that was seen during clean-up on July 21 was not representative of the levels usually found each Thursday after a week's accumulation of toner in the filters. The filters had been cleaned one day (a Tuesday) prior to the start of the survey on July 20. The side of the HEPA filter facing the hood was also vacuumed using the shop vacuum. The company owner stated that it is cleaned thoroughly approximately every six weeks. Though the microparticle filter was removed from its position in the hood to be vacuumed, neither the HEPA filter nor the charcoal filter were removed from their position in the hood.

After vacuuming the filters, the dump buckets from under the hoods were emptied. This required the worker to go underneath the hood, unseal the plastic bag in which the toner had been collected, remove and tie it for disposal, and replace it with another bag. Other tasks included wet mopping the cartridge recycling area, wiping toner from the work bench and from the outside of the hood, and cleaning the HEPA filters in the vacuums located under the work benches.

Latex gloves were worn during cleaning, but respiratory protection was not worn.

Organic Vapor Exposures from Re-inking and Cartridge Recycling Operations

Ribbon and ink jet cartridge re-inking as well as some of the activities from toner cartridge recycling released volatile organic compounds into the work environment. Most of the movable parts of the toner cartridge are lubricated as they are reassembled. The various substances used to lubricate toner cartridges are a potential source for release of volatile organic compounds into work air. The ink solvents applied to dot matrix printer ribbons and ink jet cartridges during re-inking operations represent a second major source for the release of organic compounds into workroom air. Based on review of material safety data sheets and on bulk air sampling results for organic compounds, additional air samples were taken to quantify isopropanol, n-hexane, methyl isobutyl ketone (MIBK), benzene, styrene, toluene, and 1,1,1-trichloroethane (TCE).

On July 20, approximately 35 dot matrix printer ribbons were re-inked and two ink jet cartridges were refilled. The following day, approximately 40 dot matrix printer ribbons were re-inked. According to an employee, this was routine production. Air samples collected during these two days showed that styrene and n-hexane were below detectable limits (this corresponds to a minimum detectable concentration (MDC) of approximately 0.04 ppm for styrene and approximately 0.05 ppm for n-hexane). Concentrations of benzene and MIBK were all below the minimum quantifiable concentrations, approximately 0.17 ppm for benzene and 0.14 ppm for MIBK. Isopropanol, toluene, and 1,1,1-TCE were present at quantifiable concentrations in the area and personal samples. Isopropanol was a component of the re-inking process and used to clean toner cartridges. The average, personal isopropanol exposure, combined for workers from both the work bench and ink bench locations, was 12.7 ppm as a TWA; this average includes the 4 personal samples collected during two days of sampling. This average exposure level, as well as the individual exposures, were well below existing exposure standards and criteria of OSHA, NIOSH, and ACGIH (all 400 ppm as a TWA). The average 1,1,1-TCE exposure, 1.0 ppm, was also low by comparison to existing OSHA, NIOSH, and ACGIH exposure standards (all 350 ppm as a TWA). Trichloroethane was a component of lubricants used on toner cartridge parts during reassembly. Only 4 of the 16 toluene samples had quantifiable concentrations (Approximately 0.05 ppm based on the air volume sampled). The toluene concentrations and personal exposures measured during this survey were all well below the exposure standards enforced by OSHA and the exposure criteria recommended by ACGIH and NIOSH as previously discussed. Exposures to isopropanol, toluene, and 1,1,1-TCE were also below the ACGIH TLVs as calculated for mixtures of substances with similar, combined health effects.[7-9]

Current heating, ventilation, and air-conditioning (HVAC) practices in use at this facility did not provide for mechanical outside air intake. Consequently, the dilution of volatile organic compounds released into room air from recycling operations was limited. Although sample numbers were small, the CO_2 sampling results seem to corroborate this observation. Comparison of the ambient and indoor CO_2 concentrations during both days of sampling suggests a reduced outside air intake, poor air distribution, or possibly both. Carbon dioxide is a normal constituent of exhaled breath and, if monitored, can be used as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. Indoor CO_2 concentrations are normally higher than the generally constant outdoor CO_2 concentrations (range 300-350 ppm). The mean carbon dioxide concentration from the two samples taken outside the building was 350 ppm. Indoor CO_2 concentrations measured in the toner cartridge recycling area of the back room were 1,700 ppm on July 20 and 1,000 ppm on July 21. When indoor CO_2 concentrations exceed 1000 ppm in areas where the only known CO_2 source is exhaled breath, inadequate ventilation is suspected. CO_2 concentrations in the concentration range measured during this survey do not represent a health hazard. However, they do indicate that the air concentrations of other contaminants normally present in work environments may also be elevated and, in combination, may be contributing to health complaints, such as, headaches, fatigue, and eye and throat irritation. Carbon dioxide concentrations of 1000 ppm or more have been cited in office buildings as a marker of inadequate outdoor air intake and ventilation system deficiencies. Carbon dioxide concentrations in this concentration range have also been associated with many of the respiratory symptoms described above among workers in office settings.[11]

Thermal Degradation of Plastics

The toner hoppers of most toner cartridges have plugs which are easily removed to refill the toner. However, the toner hoppers of certain cartridges are sealed. To gain access to the toner, a hole was burned into the side of the plastic toner cartridge using an electric hot wire. This process generated visible smoke and fumes in the breathing zone of the worker; the entire process generally took less than one minute to complete so the exposure period was brief. On the first day of the survey (July 20), 14 toner cartridges were recycled and 3 of these required that the electric hot wire be used to gain access to the toner. On July 21, a total of 9 cartridges were recycled; 2 of these were cartridges on which a soldering gun was used to open the cartridge. One other cartridge was opened with an electric hot wire.

When plastics are heated to high temperatures, various thermal decomposition products are produced. Thermal degradation of plastics can release hydrocarbons including polycyclic aromatic hydrocarbons (PAHs) and other toxic or irritating gases.(22,23) Hydrocarbons describe a large class of chemicals which are organic (i.e., containing carbon); many have sufficiently high vapor pressure to allow some of the compound to exist in the gaseous state at room temperature. Not all hydrocarbons exhibit the same toxicologic effects; therefore, exposure criteria are dependent on the particular hydrocarbon and its toxic effect. Generally, overexposure to hydrocarbon substances may cause irritation of the eyes, respiratory tract, and skin. Since they are central nervous system depressants, overexposure may also cause fatigue, weakness, confusion, headache, dizziness, and drowsiness.(24,25) Polycyclic aromatic hydrocarbons are aromatic compounds that are often associated with the combustion or pyrolysis of organic matter, especially coal, wood, and petroleum products including some plastics. Combustion products associated with these materials have been demonstrated to contain compounds that have been shown to cause cancer in laboratory animals and, in some cases, humans. There are few dose-related relationships for the PNA mixtures and no "safe" exposures to PNA aerosols have been established. Since the application of laboratory animal data for PNA compounds to estimate human risk is difficult, any occupational exposure to potentially carcinogenic matter is a cause for concern and exposures should be kept to an absolute minimum.(26-28)

As previously discussed, the burning of toner cartridges was brief at this work location. The exact composition of the toner cartridge cassettes was not known prior to the survey; however, some of the potential air contaminants generated by the brief plastic burning operation were quantified to the extent possible using short-term indicator tubes. On two separate occasions, short-term indicator tube samples for formaldehyde indicated that 0.4 ppm and 0.5 ppm of formaldehyde were generated in the workers breathing zone during the use of the electric hot wire to burn into a toner cartridge. These short-term formaldehyde exposures exceed the ACGIH ceiling exposure limit of 0.3 ppm. Concentrations were also high by comparison to the NIOSH recommendations to reduce formaldehyde exposures to the lowest feasible limit.(8,9) Formaldehyde concentrations did not exceed the OSHA PEL as a STEL, 2 ppm. The short-term indicator tubes used to take these measurements are cross-reactive with styrene; the presence of styrene in work air could cause a positive interference for formaldehyde by this sampling method. Styrene and styrene polymers are potential thermal degradation products produced during the burning of plastics containing polystyrene.(22,23) Styrene was detected in the bulk organic vapor samples; although, styrene concentrations were below detectable levels in the long-term, charcoal tube samples taken at the location where toner cartridge melting was done. As previously mentioned, the minimum detectable concentration for styrene was approximately 0.04 ppm as a TWA (depending on air volume sampled). It is possible that brief styrene concentration peaks caused a positive interference with formaldehyde at styrene concentrations below 0.04 ppm as a TWA. In the absence of short-term styrene measures, the formaldehyde concentrations are regarded as a potential occupational exposure problem and should be corrected with appropriate controls. This would also address potential exposure hazards from PNAs or other thermal degradation products from cartridge melting operations.

Symptoms of exposure to low concentrations of formaldehyde include irritation of the eyes, throat and nose, headaches, nausea, congestion, skin rashes, and, in some individuals who may develop hypersensitivity (allergy) asthma. It is difficult to ascribe specific health effects to specific concentrations of formaldehyde to which people are exposed, because individuals vary in their subjective responses and complaints. Irritation symptoms may occur in people exposed to formaldehyde at concentrations as low as 0.1 parts per million (ppm), but more frequently in exposures of 1.0 ppm and greater. Some sensitive children and elderly, those with pre-existing allergies or respiratory diseases, and persons who have become allergy sensitized from prior exposure may have symptoms from exposure to concentrations of formaldehyde between 0.05 and 0.10 ppm. However, cases of formaldehyde-induced asthma and bronchial hyperactivity developed specifically to formaldehyde are relatively uncommon. Formaldehyde exposure has been identified as a possible causative factor in cancer of the upper respiratory tract in a proportionate mortality study of workers in the garment industry. NIOSH has identified formaldehyde as a suspected human carcinogen and recommends that exposures be reduced to the lowest feasible concentration.[29-32]

Other substances that can be given off during the thermal degradation of plastics include ammonia, carbon monoxide, and hydrochloric acid. Neither ammonia, carbon monoxide, or hydrochloric acid were detected by short-term indicator tube samples during the use of the electric hot wire to burn the plastic toner cartridge.

One additional process for certain IBM toner cartridges involves the use of a soldering gun to burn a small hole into the plastic pins holding the cartridge together. Formaldehyde and carbon monoxide measurements were taken during this process as well. Neither formaldehyde nor carbon monoxide were detected using short-term indicator tubes. Though this process did produce an odor from the melting plastic, no smoke was visible.

Medical

When workers were specifically asked if they felt that they had developed health problems as a result of their work at Fanelli Boys, some symptoms were reported. The symptoms of eye irritation, skin rashes, cough, and shortness of breath, were consistent with formaldehye exposure. A literature search revealed a case of industrial bronchitis from the inhalation of fumes arising from the heating of plastic airways.[33] Symptoms resolved upon cessation of exposure, but were reproduced with a pulmonary challenge test. Since one of the activities of this business is the burning of cartridges, without proper engineering controls and personal protective equipment, the potential exists for exposure to the toxic thermal degradation products of plastics.

CONCLUSIONS

Toner cartridge recycling potentially involves exposure to a high level of airborne dust comprised of toner. Toners are made predominantly of a styrene-acrylate polymer and carbon black. The use of local exhaust ventilation engineering controls at Fanelli Boys and Associates reduced personal dust exposures below the OSHA PEL and ACGIH TLV for particulate not otherwise classified. Without the use of exhaust ventilation, higher dust exposures would have occurred possibly contributing to reduced visibility, irritation of the respiratory tract, eyes, and skin.[2] Some cartridge recycling activities, done outside of the exhaust ventilation hood (toner cartridge filling) or done without the use of exhaust ventilation (clean-up activities), contributed to increased dust concentrations.

Isopropanol, toluene, and 1,1,1-trichloroethane were organic compounds present at quantifiable levels in workroom air and associated with recycling activities including re-inking ribbons and cartridges as well as toner cartridge recycling. Personal exposures and area concentrations for these compounds were low by comparison to occupational exposure standards and criteria of OSHA, NIOSH, and ACGIH. Although, the current ventilation practices in use at this facility do not provide for adequate outside air supply resulting in the recirculation of workroom air and the air contaminants generated by recycling operations.

The melting of plastic polymer toner cartridges to gain access for refilling operations created visible plumes of smoke and released plastic thermal degradation products into workroom air. Formaldehyde was one of the compounds identified by short-term indicator tube sampling methods. Short-term formaldehyde samples from this activity exceeded both NIOSH and ACGIH short-term exposure limit recommendations although these results may have been confounded by the presence of styrene. The symptoms reported during the interviews were consistent with exposures to formaldehyde.

RECOMMENDATIONS

1. The melting of plastic polymer toner cartridges to gain access for refilling operations created visible plumes of smoke and released plastic thermal degradation products into workroom air. The owner of Fanelli Boys and Associates was immediately informed of the potential exposure problems associated with this activity and given recommendations to discontinue this activity pending implementation of appropriate exposure controls. The owner indicated that an alternate drilling method would be used to access the toner in sealed cartridges instead of the electric hot wire and melting plastic. The use of local exhaust or directed dilution ventilation would also be alternative controls to reduce worker exposures to formaldehyde and other thermal degradation products if the melting of toner cartridges is continued.

2. A mechanical outside air intake should be added to the existing HVAC system to deliver outside air to the work areas; a minimum of 20 cubic feet per minute of outside air should be provided for each worker.

3. To reduce dermal exposures to toner or organic compounds in the inks or toner cartridge lubricants, protective gloves for dusts/chemicals should be worn by anyone working with these substances. Glove manufacturers should be consulted to select gloves and glove materials suitable to accommodate both the production process and to provide adequate protection for the toners, solvents, and inks in use at the workplace.

4. During the Thursday clean-up activities, a larger amount of dust is generated. To limit the amount of dust exposure during clean-up, workers should wear appropriate respiratory protection including a minimum level of respiratory protection equal to a disposable N95 respirator certified by NIOSH under 42 CFR 84. The respirators should be used as a part of a formal respiratory protection program. Additional information on respirators and respiratory protection programs can be found in the NIOSH Guide to Industrial Respiratory Protection.[34]

5. When possible, toner cartridge recycling activities should be done inside or directly in front of the local exhaust ventilation hood to ensure effective dust collection and removal for reductions in dust exposures. This would include toner cartridge refilling activities and possibly other cartridge recycling activities as appropriate. Pneumatic cleaning of dust work spaces and cartridges should be avoided or replaced by vacuum cleaning.

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