HETA 99–0137–2810
World Color Press
Effingham, Illinois

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PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Calvin Cook and Elena Page of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Jee Y. Jeong and Bradley King of HETAB, and Tony Martinez of HELD. Analytical support was provided by DART and DataChem laboratories. Desktop publishing was performed by Robin Smith. Review and preparation for printing were performed by Penny Arthur.

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For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Skin and Respiratory Symptoms, and Air Monitoring for Solvents, Aldehydes, and Resin Acids

This health hazard evaluation was requested by the union to look at breathing and skin problems in the printing and bindery departments at the World Color Press facility in Effingham, Illinois.

What NIOSH Did

We took air samples for solvents, aldehydes, and resin acids.

We talked to workers about skin and breathing problems.

We looked into other workplace hazards.

What NIOSH Found

Workers were exposed to solvents in air that were below OSHA limits.

Workers were exposed to aldehydes that were above outdoor levels.

Workers were exposed to resin acids in air.

Some workers may have skin problems and breathing problems related to work.

What World Color Press Managers Can Do

Install exhaust ventilation at presses, perfect binders, and battery chargers to lower chemicals in air.

Provide workers with gloves made of material that will protect their skin from solvents. See final report for details.

To reduce the chance of fire, replace plastic shop rag containers with metal containers that have lids.

Start a "No Smoking" program.

Improve housekeeping in the quality sample area.

Provide workers with access to a physician knowledgeable in occupational medicine and familiar with exposures in the plant.

What the World Color Press Employees Can Do

Wear gloves made of materials that will protect skin from solvents.

Stop smoking if you smoke.

Do not smoke in work areas where flammable solvents are present.

Allow fragrance inserts to air-out in the dock area before being used in the bindery department.

Report all possible work-related breathing or skin problems to company health care personnel.

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 513/841–4252 and ask for HETA Report # 99–0137–2810

NIOSH National Institute for Occupational Safety and Health

Health Hazard Evaluation Report 99–0137–2810
World Color Press
Effingham, Illinois
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SUMMARY

On March 16, 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Graphic Communications Local #391-C union to conduct a health hazard evaluation (HHE) at World Color Press located in Effingham, Illinois. Employees reportedly had unspecified respiratory problems and skin rashes that they believed were caused by occupational exposures to solvents and inks during printing and binding processes. On June 23–24, 1999, a walk-though survey was conducted to review the printing and bindery processes, conduct air sampling for potential air contaminants, and interview employees. A follow-up industrial hygiene survey was conducted on September 8–9, 1999, to measure workers' exposures to petroleum naphthas, 2-butoxyethanol, aldehydes, and resin acids (specifically abietic and dehydroabietic acids).

Full-shift personal breathing-zone (PBZ) air samples collected for petroleum naphthas on press operators and press cleaners revealed time-weighed average (TWA) exposures of 48 and 98 milligrams per cubic meter (mg/m^3), respectively. These exposures were below both the NIOSH recommended exposure limit (REL) of 350 mg/m^3 for up to a 10-hour workday, 40-hour work week, and the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) of 2000 mg/m^3. Full-shift 2-butoxyethanol exposures ranged up to 1.9 mg/m^3, below both the NIOSH REL of 24 mg/m^3 as a 10-hour TWA and the OSHA PEL of 240 mg/m^3 as an 8-hour TWA.

Full-shift PBZ air samples collected on print press operators and bindery operators for aldehydes revealed TWA concentrations up to 0.027 parts per million (ppm) for formaldehyde, 0.004 ppm for butanal, and 0.029 ppm for acetaldehyde. General area air samples collected revealed TWA concentrations up to 0.023 ppm for formaldehyde, 0.007 ppm for butanal, and 0.168 ppm for acetaldehyde. Because these aldehydes are potentially carcinogenic to humans, NIOSH recommends reducing exposures to the lowest feasible concentration (such as ambient concentrations near the workplace). Two area air samples collected outdoors revealed ambient concentrations of 0.003 ppm for formaldehyde, 0.0007 ppm for butanal, and 0.0006 ppm for acetaldehyde.

Full-shift PBZ air samples for resin acids collected on printing press operators and bindery operators revealed concentrations up to 2 micrograms per cubic meter ($\mu g/m^3$) for dehydroabietic acid, while only trace abietic acid concentrations were measured. General area air sampling revealed TWA concentrations up to 4.5 $\mu g/m^3$ for abietic acid and 9.2 $\mu g/m^3$ for dehydroabietic acid at printing presses, and up to 6 $\mu g/m^3$ for abietic acid and 77 $\mu g/m^3$ for dehydroabietic acid in the bindery department. The American Conference of Governmental Industrial Hygienists' (ACGIH) recommends reducing exposures to as low as possible. In two area air

samples for resin acids collected outdoors, no resin acids were detected. There are no established exposure criteria by NIOSH or OSHA for resin acids.

Thirty-six employees were interviewed in person by a NIOSH physician, including 2 from quality assurance, 9 from the bindery, and 25 from the pressroom. Twenty-six were selected from a list provided by the union of persons with respiratory and/or dermal complaints who were scheduled to work during the site visit. The rest were randomly selected from the schedule of workers during our visit. Interviews covered occupational, environmental, and medical histories, with special attention to the nervous, respiratory, and dermatologic systems. A temporal relationship between reported symptoms and work was sought.

Several workers reported symptoms consistent with occupational contact dermatitis. Others reported respiratory symptoms related to work. Work-relatedness could not be determined in our evaluation.

Several workers reported symptoms consistent with occupational contact dermatitis and others reported respiratory symptoms. However, the work-relatedness of the respiratory symptoms could not be determined in our evaluation. Workers were exposed to airborne concentrations of naphthas and 2-butoxyethanol that were well below their respective exposure criteria. Workers were exposed to aldehyde concentrations that were greater than levels measured outdoors. Workers were exposed to measurable airborne resin acid concentrations generated by both the printing and perfect binding processes. Dermal exposures to these chemical substances present a significant health hazard when handling inks and solvents without regular use of appropriate protective gloves, and good personal hygiene that includes frequent hand washing and wearing unsoiled work clothing. Recommendations are offered in this report to help reduce workers' exposures to air contaminants, solvents, and inks.

Keywords: SIC Code 2721 (Magazine Printing and Publishing), naphthas, stoddard solvent, 2-butoxy ethanol, aldehydes, rosin, colophony, resins, resin acids, abietic acid, dehydroabietic acid, dermatitis, sensitizer.

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INTRODUCTION

On March 16, 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request from representatives of the Graphic Communications, Local #391-C union to conduct a health hazard evaluation (HHE) at World Color Press (WCP) located in Effingham, Illinois. The request stated that employees were experiencing unspecified respiratory problems and skin rashes that they believed to be caused by exposures to solvents and inks during printing and binding processes.

In response to the HHE request, on June 23-24, 1999, NIOSH representatives conducted a walk-though inspection to review the printing and bindery processes, conducted preliminary air sampling for potential air contaminants, and interviewed employees. On September 8-9, 1999, based on preliminary air sampling results, a follow-up industrial hygiene survey was conducted to measure workers' exposures to naphthas, 2-butoxyethanol, and rosin by measuring aldehydes and resin acids (specifically abietic and dehydroabietic acids). A summary of the industrial hygiene air sampling results was presented to management and union representatives in an interim letter dated December 7, 1999.

BACKGROUND

Process Description

WCP is a printing company that provides printing, binding, and distribution services for consumer magazines. The Effingham Division of WCP is a 580,000 square foot facility that employs about 900 hourly and 100 administrative employees over three shifts. There are approximately 350 employees in the printing department or press room and 550 employees in the bindery department. Of the 350 printing department employees, 218 work in the pressroom itself, and the rest are support personnel. WCP corporate headquarters was previously located in Effingham, and there are about 100 corporate employees still stationed at the plant. The work areas of concern for this HHE included the printing and bindery departments.

Printing Department

The printing operation at WCP is an automated lithography (off-set) process that prints, dries, cuts, folds, and assembles magazines into a crude form called signatures. The 12 high-speed printing presses in operation are manned by printing press operators. Four types of colored inks (black, blue, red, and yellow) are printed on wide-web rolls of bleached paper. The chemical composition of inks varies, but most include a complex mixture of pigments, petroleum distillates, and resins (including epoxy and phenolic resins). Some magazine covers require a varnished finish that is applied by catalytic coating units on presses #219 and #228. This varnish coating contains 2-butoxyethanol. After printing and coating, the ink is dried by gas-fired dryer ovens operating at 350°F. Signatures are then cut, folded, assembled, and prepared for binding. Local exhaust ventilation (LEV) is present at catalytic units and dryer ovens of each press. Numerous roof exhaust fans are present throughout the plant.

During the printing operation, workers routinely use blanket wash solutions and wetting agents (also called fountain solutions) as solvent cleaners to remove ink from printing press equipment. These solvents are manually applied by workers using shop rags while wearing nitrile rubber gloves for hand protection. Press equipment is partially cleaned or wiped down about 2-3 times each shift. A more thorough cleaning on each press is done a few times each week, with cleaning sessions lasting about an hour. Some cleaning tasks require three workers several hours to accomplish. Some printing presses have an auto-blanket wash system that is capable of cleaning during operation. Blanket wash

solutions are combustible liquids (flashpoint greater than 100°F) made of petroleum naphtha. Wetting agents (flashpoint less than 100°F) are made of alcohol or an alcohol substitute. Over the course of a workday, solvent-saturated shop rags are accumulated and stored in metal or plastic containers. An anti-static silicon solution is also handled by workers during printing. The anti-static solution is manually applied to press rollers several times each shift to achieve a certain print quality.

Bindery Department

After magazines are printed and assembled, binding is done by two types of binder machines, inserter binders and perfect binders. While inserter binders use staples to bind the spine of magazines, perfect binders use a hot-melt adhesive (glue) containing rosin (colophony). The original form of the glue material is a conglomerate of solid pellets, which is electrically heated (up to 350°F) to a molten form by premelters and hot-melt pots. The hot glue is applied to the spines of magazines for binding. No LEV is present at hot melt pots and premelters.

Other Work Areas of Concern

During the course of the HHE, NIOSH investigators were asked by workers to look into additional health and safety concerns. Between the press and bindery departments is a battery-charging operation that is comprised of more than 55 large industrial-sized lead acid batteries used for the facility's powered-industrial trucks. Some workers reported experiencing eye and respiratory irritation when working nearby or walking past the battery-charging operation.

Bundles of fragrance inserts (or scent scripts) are manually loaded into bindery machines. Before fragrance inserts are brought into the bindery area, it is normal procedure for dock workers to allow these inserts to air-out for a day in the dock area. When this procedure is not followed, bindery workers reported experiencing headaches. Administrative controls are practiced to reduce worker complaints by rotating workers assigned to loading fragrance inserts.

A third concern involved cleaning ink-jet printing units at a small degreaser tank. Cleaning is done by hand, using a methanol solution and shop rags to remove ink. LEV was present at the degreaser tank to control worker exposures to methanol vapors. A worker wore latex rubber gloves and nitrile rubber gloves while cleaning printing units.

In the quality sample area, workers were concerned about their exposure to dusts that accumulated on work surfaces and equipment. The dust is a mixture of paper and silicon that is dispersed from nearby printing presses.

NIOSH investigators noted several employees smoking in the plant during our visit. There are no designated smoking areas so smoking is allowed throughout the plant.

METHODS

Industrial Hygiene Evaluation

During the initial site visit on June 23-24, 1999, a walk-through survey was made, material safety data sheets (MSDSs) were reviewed, and preliminary air sampling was performed. Using NIOSH method 2549, four area air samples were collected on thermal desorption tubes and analyzed qualitatively by gas chromatography (GC) to screen for potential air contaminants in the printing and bindery departments.[1] On September 8–9, 1999, a follow-up visit was made to conduct industrial hygiene monitoring in the press and bindery departments that included personal breathing-zone (PBZ) air sampling on workers to measure their exposures to potential air

contaminants. General area air sampling was also conducted at printing presses and perfect bindery machines.

In the press department during first shift, PBZ air samples were collected on press operators to measure their exposures to naphthas, 2-butoxyethanol, aldehydes, and resin acids. To collect air samples that would represent workers' highest possible exposures, operators on presses #226, #227, and #231 were targeted because these presses were faster than the other presses, and typically used more blanket wash solution. During the second shift on September 8, PBZ air samples for petroleum naphtha were collected on workers who were cleaning presses #219 and #231.

In the bindery department during first shift, PBZ air samples for aldehydes and resin acids were collected on a bindery operator working near a hot melt pot. Only one air sample was collected for each of these two groups of air contaminants.

The following provides air sampling and analytical information for each air contaminant evaluated during this HHE.

Petroleum Naphtha: Fifteen PBZ and three area air samples for naphthas were collected on charcoal tubes connected to air sampling pumps calibrated at a flowrate of 200 cubic centimeters per minute (cc/min). Air samples were analyzed by GC, in accordance with NIOSH method 1550.[1]

2-Butoxyethanol: Four PBZ and one area air samples for 2-butoxyethanol were collected on charcoal tubes connected to air sampling pumps calibrated at a flowrate of 50 cc/min. Air samples were analyzed by GC, in accordance with NIOSH method 1403.[1]

Aldehydes: Twelve PBZ and 13 area air samples for aldehydes were collected on 2,4-dinitrophenyl-hydrazine (DNPH)-treated silica gel tubes connected to air sampling pumps pre- and post-calibrated at a flowrate of 1 liter per minute (Lpm). Air samples were analyzed by high-pressure liquid chromatography (HPLC), in accordance with NIOSH method 2016.[1]

Resin Acids: Thirteen PBZ and 11 area air samples for resin acids were collected on polytetrafluoroethylene (PTFE) filters using air sampling pumps pre- and post-calibrated at a flow rate of 2 Lpm. Analysis was performed by a HPLC procedure developed by a NIOSH laboratory for the analysis of abietic acid and dehydroabietic acid.

Other Industrial Hygiene Activities

To address worker concerns for potential exposure to acid gases at the battery-charging operation, information about the process was gathered. Ventilation smoke tubes were used to determine directional airflow around the batteries being recharged and to qualitatively evaluate the LEV serving the operation. The relative effectiveness of exhaust was determined by observing the airflow pattern to the exhaust hood entry when smoke was released from batteries on charge.

To investigate concerns regarding fragrance inserts, information was gathered about the use of odor control methods, administrative controls, and work practices.

In the quality sample area, a visual inspection was made to determine the extent of paper dust accumulation on work surfaces. Information was gathered about the housekeeping frequency and methods used to remove dust.

Medical

During the June site visit, 36 current employees were interviewed; 2 of those interviewed were from the quality sample area (22% of all quality sample employees), 9 were from the bindery (1.6% of all bindery employees), and 25 were

from the pressroom (7.1% of all printing department employees). Twenty-six of the 36 interviewed were identified by the union as persons with respiratory and/or dermal symptoms or complaints. Twenty-four were scheduled to work during the site visit, and two asked to be interviewed even though they were not scheduled to work. The 26 self-selected employees included 8 of 9 bindery employees, 16 of 25 pressroom employees, and 2 of 2 quality sample employees. The remaining 10 interviewed employees were randomly selected from those working in all three areas during our visit. In addition to the 36, one former employee, whose name was provided by the union, was interviewed by telephone. This individual provided medical records for review.

Interviews included occupational, environmental, and medical histories, with special attention to the nervous, respiratory, and dermatologic systems. Questions were asked concerning the temporal relationship of reported symptoms to work activities.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, which potentially increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[2] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs®),[3] and (3) the U.S. Department of Labor (DOL), Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[4] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs®, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 95-596, sec. 5.(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Organic Solvents

The term solvent applies to any substance that dissolves another substance, yielding a solution. They can be water based (aqueous) or hydrocarbon based (organic). Most industrial solvents are organic, and are used for tasks such as cleaning, degreasing, thinning, and extraction.[5] Inhalation and dermal exposure are both important routes of exposure in industrial settings. Absorption through the skin depends upon the degree of both lipid and water solubility of the solvent.[5] Almost all organic solvents cause irritation of the skin because they remove fat from the skin. Inhalation of organic solvents can irritate the respiratory system. This irritation is usually restricted to the upper airways, mucous membranes and eyes, and it generally resolves quickly without long-term effects.[5] In addition, almost all volatile, fat-soluble organic solvents can acutely cause nonspecific central nervous system depression. In fact, several were used as surgical anesthetics in the past.[5] The symptoms are similar to those from drinking alcoholic beverages, ranging from headache, nausea and vomiting, dizziness, slurred speech, impaired balance, disorientation, and confusion at lower exposure levels to death from respiratory depression at very high exposure levels.

Petroleum Naphtha

Naphtha is comprised mainly of aliphatic hydrocarbons.[6,7] Since naphthas are mixtures of aliphatic hydrocarbons, the evaluation criteria are based upon the most commonly available varieties (coal tar, petroleum, rubber solvent, varnish makers' and painters' naphtha, mineral spirits, and stoddard solvents). The OSHA PEL for petroleum naphtha is 2000 milligrams per cubic meter (mg/m^3) as an 8-hour TWA, and the NIOSH REL is 350 mg/m^3 for up to a 10-hour workday, 40-hour work week.

2-Butoxyethanol

2-butoxyethanol, also known as ethylene glycol monobutyl ether, or butyl cellosolve®, is a colorless liquid solvent with a mild ether odor.[8,9] 2-butoxyethanol is a widely used solvent and cleaning agent. The low vapor pressure of 2-butoxyethanol is such that high air concentrations are unlikely; however, the material can be absorbed through the skin. The NIOSH REL for 2-butoxyethanol is 24 mg/m^3 as a 10-hour TWA. The REL was extrapolated from animal toxicity data (rats).[8] While intended to prevent hematotoxicity, the REL should also prevent eye and mucous membrane irritation. The OSHA PEL is 240 mg/m^3 as an 8-hour TWA.

Aldehydes

Formaldehyde

Formaldehyde is a flammable, colorless gas at room temperature. It has a pungent odor that can be detected at 0.05 parts per million (ppm).[10] It is produced by the oxidation of methanol using a metal oxide or silver catalyst process. It is most commonly available in a 30-50% aqueous solution called formalin.[11] Tobacco smoke is also a source of formaldehyde.[12]

Formaldehyde is highly water-soluble and therefore, with inhalation exposure, exerts its primary effects on the upper respiratory tract. The no-observable-effect level for eye and respiratory irritation is 0.40 ppm.[11] Studies of acute changes in pulmonary function are not completely consistent, but indicate that formaldehyde does not cause significant airway hyper-responsiveness or bronchoconstriction. Exposure to very high levels (50 to 100 ppm) may result in chemical pneumonitis and pulmonary edema.[10,11] In addition, formaldehyde is a skin irritant and sensitizer. The International Agency for Research on Cancer (IARC) classifies formaldehyde as group 2A, probably carcinogenic to humans. The

evidence is strongest for nasopharyngeal cancers.[12] The OSHA PEL is 0.75 ppm as an 8-hour TWA. ACGIH recommends a TLV® ceiling concentration of 0.30 ppm.

NIOSH testimony to DOL on May 5, 1986, stated the following: "Since NIOSH is not aware of any data that describe a safe exposure concentration to a carcinogen, NIOSH recommends that occupational exposure to formaldehyde be controlled to the lowest feasible concentration; 0.1 ppm in air by collection of an air sample for a 15-minute period as described in NIOSH analytical method 3500, which is the lowest reliable quantifiable concentration at the present time." NIOSH also lists a REL for formaldehyde of 0.016 ppm, for up to a 10-hour TWA exposure (again using NIOSH analytical method 3500) and indicating that this is the lowest feasible reliable quantifiable concentration at the present time. Investigators should be aware that formaldehyde levels can currently be measured as below 0.016 ppm. It may be appropriate to refrain from using numerical limits and, instead, state that concentrations should be the lowest feasible (in some situations, this may be limited by the ambient background concentration).

Butanal

Butanal (also called n-butyraldehyde) is an aliphatic aldehyde compound that is commonly used as an intermediate in chemical synthesis used in manufacture of rubber, synthetic resins, solvents, and plasticizers. In terms of acute toxicity, butanal is considerably less toxic than similar saturated aliphatic aldehydes (i.e., acetaldehyde) by cutaneous, oral, and inhalation routes of exposures in different animal species.[13] In humans butanal may produce irritation of the eyes and upper respiratory tract. There is no REL for butanal. However, because testing has not been completed to determine the carcinogenicity of butanal, NIOSH recommends that careful consideration should be given to reducing exposures to this substance. The American Industrial Hygiene Association (AIHA) recommends a workplace environmental exposure level (WEEL) of 25 ppm.[14] There are no exposure criteria established by OSHA or ACGIH.

Acetaldehyde

Acetaldehyde is a colorless, flammable liquid with a pungent odor. It is primarily used as a substrate for acedic acid manufacture, and is present in the paper industry, cosmetic industry, fuel composition, and in glue products. Acetaldehyde has been detected in the smoke from tobacco and from burning wood.[9,13]

In humans, the primary acute effects caused by exposure to airborne acetaldehyde include irritation of the eyes, skin, and upper respiratory tract.[9,13] Direct eye contact with liquid acetaldehyde can produce a painful burning sensation, lacrimation, and blurred vision.[13] Exposure to acetaldehyde has produced nasal tumors in rats and laryngeal tumors in hamsters.[9,12] NIOSH considers acetaldehyde a potential occupational carcinogen and recommends reducing exposures to the lowest feasible concentration. The OSHA PEL for acetaldehyde is 200 ppm as an 8-hour TWA. ACGIH has established a TLV® of 25 ppm as a ceiling limit.

Rosin (Colophony) and Resin Acid Compounds

Rosin (colophony) is a natural substance obtained from various species of pine trees with applications in industrial processes, particularly in the electronics and printing industries. Rosin is also present in a wide variety of products both at work and at home that include soldering flux, printing inks, paper sizing, varnishes, glues, adhesive tape, cutting fluids, cosmetics, and soaps.[13,15]

The chemical composition of natural, unmodified rosin is a complex mixture of about 90% resin acids and about 10% ester, aldehydes, and

alcohols.[13,15] About 90% of the resin acid fraction in rosin consists of isomeric forms of abietic acid, and the remaining 10% a mixture of dehydroabietic acids.[13,15] Air sampling methods recently developed to measure airborne resin acids have identified abietic and dehydroabietic acids.[16,17,18,19] Other resin acids identified in air include oxidized forms that include 15-hydroperoxyabietic acid, 7-hydroxydehydroabietic acid, and 7-oxodehydroabietic acid.[20]

Rosin is widely known as a skin and respiratory sensitizer that causes allergic contact dermatitis and occupational asthma.[21,22,23,24,25] Exposure may occur in heated and unheated forms of rosin containing materials.[26] Resin acids are reported to be the components in rosin that are responsible for causing dermal and respiratory sensitization.[15]

NIOSH has established a 15-minute ceiling limit for rosin core solder pyrolysis products of 0.08 ppm, measured as formaldehyde. OSHA has established an 8-hour TWA PEL of 0.08 ppm, also measured as formaldehyde. However, based on recent studies that have better characterized the chemical components of rosin and its thermal decomposition products, the suitability of measuring formaldehyde as a marker for rosin thermal decomposition products is questionable.[13,15,17,18,20] Determining exposure to resin acids is considered a more appropriate technique for assessing exposures to rosin and its thermal decomposition products.[13,17,18,20]

ACGIH has not established a numerical TLV® for rosin core thermal decomposition products, but recommends that exposures to rosin and resin acids be maintained to the lowest achievable concentration using engineering controls and/ or personal protective equipment.[13]

Epoxy and Phenolic Resins

The following information about phenolic and epoxy resins is presented because these substances were present in the ink formulations at WCP and can cause dermatitis. There are no air sampling methods available to specifically measure phenolic and epoxy resin compounds in air. Instead, potential thermal decomposition products (i.e., resin acids) are measured.

Epoxy resin compounds contain a number of chemicals, including hardeners and diluents. They are typically formed by the reaction of epichlorhydrin and a diglycidyl ether of bisphenol. They are widely used in coatings, laminates, adhesives, and industrial paints.[27] Epoxy resins are skin and respiratory sensitizers.[27]

Phenolic resins are made by reacting phenol with an aldehyde, most commonly formaldehyde. They are used extensively in plywood lamination, as binders for foundry sand, and in combination with other adhesives to increase moisture resistance. They are dermal sensitizers, irritants, and depigmenters.[28,29]

Environmental Tobacco Smoke

Environmental tobacco smoke (ETS) is harmful to the health of nonsmokers. NIOSH has concluded that occupational ETS exposure is associated with an increased risk of lung cancer and possibly heart disease. Other health effects associated with ETS include reduced pulmonary function, irritation of the eyes and nose, headache, and cough.[30,31]

Health Effects

Occupational Asthma

Occupational asthma (OA) is a disease characterized by variable airflow obstruction and/or airway hyper-responsiveness due to agents in the workplace. OA affects only a portion of an exposed population and develops after a latent period ranging from months to years. The usual symptoms are coughing, shortness of breath, and chest tightness. Symptoms of OA can occur within minutes of exposure, but may also occur several hours after exposure. Symptoms of OA

usually get worse as the workweek continues, but improve on weekends and vacations. As OA progresses, symptoms may take days to weeks to improve after exposure has ceased.[32]

Contact Dermatitis

Contact dermatitis is by far the most common occupational skin disease. Eighty percent of contact dermatitis is irritant in nature, and 20% is allergic.[33] Irritant contact dermatitis (ICD) is not an immune-mediated reaction. It typically presents as dry, cracked, red, and itchy skin. Allergic contact dermatitis (ACD) is an immune-mediated reaction; ACD is a Type IV, delayed hypersensitivity reaction and is T-cell mediated. ACD presents as red, itchy skin with papules or vesicles 12-48 hours after contact with the allergen. Chronic ACD can be difficult to distinguish from ICD.

Contact dermatitis usually occurs on areas of the skin which have direct contact with the substance of concern. This usually happens when workers handle substances directly, but it can also occur via airborne contact with vapors, droplets, or solid particles such as dust. Contact dermatitis from airborne substances typically involves parts of the body that are exposed to the air: the face, neck, upper chest, hands, wrists, and arms. Upper eyelids are especially susceptible to airborne irritants or allergens.[34]

RESULTS

Industrial Hygiene Air Sampling

Petroleum Naphtha

Air sampling results for naphtha are presented in Tables 1 and 2. Of the 11 full-shift PBZ air samples collected on press operators, the highest full-shift TWA concentration was 48 mg/m^3, well below both the NIOSH REL of 350 mg/m^3 as a 10-hour TWA and the OSHA PEL for naphtha of 2000 mg/m^3 as an 8-hour TWA. Four air samples collected on press cleaners revealed full-shift TWA concentrations up to 98 mg/m^3, also below the NIOSH REL and OSHA PEL.

2-Butoxyethanol

Four PBZ air samples collected on press operators for 2-butoxyethanol revealed full-shift TWA concentrations that ranged from 1.2 mg/m^3 to 1.9 mg/m^3, well below the NIOSH REL of 24 mg/m^3 as a 10-hour TWA and the OSHA PEL of 240 mg/m^3 as an 8-hour TWA. An area air sample collected at press #219 revealed an TWA concentration of 2.5 mg/m^3.

Aldehydes

Air sampling results for aldehydes are presented in Tables 3 and 4. In the press department, full-shift PBZ air samples collected on press operators for aldehydes revealed TWA concentrations up to 0.027 ppm for formaldehyde, 0.004 ppm for butanal, and 0.029 ppm for acetaldehyde. Five general area air samples collected near printing presses revealed full-shift TWA concentrations up to 0.016 ppm for formaldehyde, up to 0.003 ppm for butanal, and up to 0.013 ppm for acetaldehyde.

In the bindery department, a PBZ air sample revealed a full-shift TWA concentration of 0.017 ppm for formaldehyde, 0.002 ppm for butanal, and 0.016 ppm for acetaldehyde. Six area air samples collected at premelters and hot-melt pots revealed TWA concentrations up to 0.023 ppm for formaldehyde, 0.007 ppm for butanal, and 0.168 ppm for acetaldehyde.

Because exposure to these aldehydes is potentially carcinogenic to humans, NIOSH recommends reducing exposures to their lowest feasible concentration. Ambient concentrations nearby the workplace may also represent the lowest feasible concentrations. Two area air samples collected outdoors revealed ambient concentrations of

0.003 ppm for formaldehyde, 0.0007 ppm for butanal, and 0.0006 ppm for acetaldehyde. Likely sources of formaldehyde in the workplace are from heating glue (containing colophony) at perfect binder machines, and from tobacco smoke.

Resin Acids

Air sampling results for resin acids are presented in Tables 5 and 6. In the press department, 12 full-shift PBZ air samples collected on press operators for resin acids revealed TWA concentrations up to 2 micrograms per cubic meter ($\mu g/m^3$) for dehydroabietic acid. Only trace amounts of abietic acid were measured. Six area air samples collected for resin acids at printing presses revealed TWA concentrations up to 4.5 $\mu g/m^3$ for abietic acid and 9.2 $\mu g/m^3$ for dehydroabietic acid. These resin acid concentrations were measured in the presence of local exhaust ventilation at dryer ovens. The likely source of resin acids are thermal decomposition products of the epoxy and phenolic resin compounds present in inks.

In the bindery department, the PBZ air sample collected on a bindery worker revealed a TWA concentration of 2 $\mu g/m^3$ for dehydroabietic acid; abietic acid was not detected. Five area air samples collected at premelters and hot melt pots revealed TWA concentration up to 6 $\mu g/m^3$ for abietic acid and 77 $\mu g/m^3$ for dehydroabietic acid. No resin acids were detected in two area air samples collected outdoors.

Other Observations

For hand protection, latex rubber gloves and nitrile rubber gloves were furnished to workers who cleaned ink-jet printers using methanol. These glove materials do not adequately protect workers from skin exposures to methanol. Gloves made of butyl rubber are impermeable to methanol and will better protect against skin exposure.

The local exhaust ventilation hoods serving the battery recharging operation were about 2 feet from the sources of emission, which may be too far for effective control. Ventilation smoke tubes showed an airflow pattern moving away from the battery-chargers and towards press #213. In absence of air monitoring data, it is conceivable that the battery-charging operation is emitting sulfuric acid gas or other irritative chemical compounds, which is then drawn through the area where some workers reported smelling irritative odors.

An inspection of the quality sample area revealed accumulated dust on work surfaces and equipment. While some work areas are routinely cleaned to remove dust by vacuuming and blowing (using compressed air), the quality sample area appeared to be overlooked.

Medical Evaluation

Interviewed workers reported a mean duration of employment of 22 years (range 2–29). The average age of the interviewed workers was 46 years.

Both workers in the quality sample area reported cough and shortness of breath at work. Symptoms generally resolved with leaving work in one, but not in the other. One reported being diagnosed with asthma secondary to toluene diisocyanate (TDI) by a physician.

Four of the nine bindery employees interviewed reported no work-related symptoms. Of the remaining five, one reported occasional nosebleeds after cleaning the inkjets, one reported a sore throat at work that could be prevented by wearing a dust mask, and one reported chest congestion and wheezing that occurs after spending a couple of days cleaning the ink-jets. Two had dermal complaints (one had a rash on the lower leg and one had dry, cracked skin on the thumb and index finger of the dominant hand).

Seven of the 25 pressroom employees interviewed reported no work-related symptoms. Sixteen of the 18 with symptoms reported a history of skin problems (although not all employees related them to work) and 6 were currently experiencing skin problems. Of the six with current skin problems, one had been diagnosed with psoriasis. Of the remaining five, two had a rash on both forearms, and three had a variety of different skin lesions. One worker reported shortness of breath and wheezing at work, one reported burning of the eyes at work, and one reported episodes of possible anaphylactic symptoms that had occurred both at work and at home. The former employee reported a variety of symptoms thought to be related to work, but medical records revealed no occupational medical problems.

DISCUSSION

Although a variety of different skin conditions were reported, several interviewed workers reported symptoms which were consistent with contact dermatitis, i.e., a rash on areas of the skin which are in direct contact with certain substances. Most of the workers with this rash were pressroom workers who had dermal contact with solvents and one worked in the bindery where the printed product is handled. Several substances in use at WCP are capable of causing both allergic and irritant contact dermatitis. These include solvents, resin acids, epoxy resins, phenolic resins, and formaldehyde. Although the extent to which these workplace exposures are responsible for the observed contact dermatitis is unknown, the history and physical exam findings are consistent with occupational contact dermatitis in some of the interviewed workers. None of these workers had a pattern of dermatitis indicative of an airborne exposure as the cause, suggesting the primary mode of exposure was direct dermal contact. While gloves can prevent contact with chemicals, they can also cause irritant contact dermatitis, and in some cases, allergic contact dermatitis.

Several employees from the three areas of the plant we evaluated reported respiratory symptoms. Although one worker reported being diagnosed with occupational asthma secondary to TDI by a personal physician, TDI is not used in the plant and does not appear to be a byproduct of any of the processes in the plant. Several substances in use at WCP are capable of causing respiratory irritation or asthma, including solvents, resin acids, epoxy resins, phenolic resins, formaldehyde, and environmental tobacco smoke. Solvent concentrations and potential sensitizers such as resin acids and formaldehyde were below the levels at which eye and respiratory irritation has been reported; however, it is unknown what levels cause sensitization or symptoms among those who are sensitized. Sensitized individuals can experience health effects to substances at extremely low levels.

Based on the results of area air samples, the highest potential for respiratory exposure to resin acids, particularly dehydorabietic acid, is likely to occur among bindery operators near premelters and hot melt pots where dehydroabietic acid was measured as high as 77 $\mu g/m^3$ as a full-shift TWA. Due to lack of participation by bindery workers, only one PBZ air sample was collected, which revealed a full-shift TWA concentration of 2 $\mu g/m^3$. This one air sample is insufficient to adequately characterize workers' exposures in the bindery department. Therefore, additional PBZ air sampling for resin acids is necessary to better document worker exposures in the bindery department.

Worker exposures to aldehydes were well within exposure limits established by OSHA and ACGIH. However, formaldehyde and acetaldehyde concentrations were greater than outdoor levels and workers' exposures exceeded the more stringent NIOSH RELs.

During the course of the HHE, NIOSH investigators were asked by workers to look into additional safety and health concerns, including the presence of accumulated paper dust in

the quality sample area, symptoms of eye and respiratory irritation near the facility's battery-charging operation, and headaches associated with loading fragrance inserts in the bindery department. Although no air sampling was done to determine workers' exposures to paper dust, sulfuric acid gas, and constituents of the fragrance inserts, previous NIOSH field studies have shown respiratory irritation from exposures to these substances. Sulfuric acid is a known respiratory and mucous membrane irritant.[9]

CONCLUSIONS

Printing operators were exposed to air concentrations of naphthas and 2-butoxyethanol that were well below their respective exposure criteria. Industrial hygiene monitoring measured resin acid concentrations generated by both the printing and perfect binding processes, but PBZ air sampling was insufficient to adequately characterize exposures. Dermal exposures to many substances at WCP present a potential health hazard when handling substances without regular use of appropriate protective gloves, and good personal hygiene that includes frequent hand washing and wearing unsoiled work clothing.

Some of the interviewed workers reported symptoms consistent with occupational contact dermatitis and respiratory irritation or asthma. Although several substances in use at WCP are capable of causing these types of health effects, based on our evaluation we are not able to determine whether any of the reported conditions are caused by work exposures at WCP. Despite PBZ concentrations well below current exposure criteria, it is possible that individual employees may still experience respiratory symptoms. Sensitized individuals can experience health effects to substances at extremely low levels.

RECOMMENDATIONS

Since resin acids are known skin and respiratory sensitizers, exposures should be reduced to their lowest feasible concentrations. Local exhaust ventilation should be provided at premelters and hot melt pots to control resin acids at their source of generation. Also, because press operators were exposed to resin acid concentrations, the local exhaust ventilation currently provided at dryer ovens of each printing press should be examined by a qualified industrial ventilation engineer to ensure exhaust air flow is as designed. If newly installed local exhaust ventilation is provided at premelters and hot melt pots, or if existing exhaust ventilation at presses is modified, additional air sampling for resin acids should be made to evaluate their effectiveness.

To protect hands from chemical exposures, workers should be provided and instructed to wear gloves made of materials that are impermeable to chemicals being used. For solvents containing petroleum naphtha, nitrile rubber gloves are proven to provide adequate skin protection. For handling methanol, gloves made of butyl rubber are recommended.[35]

To reduce the risk of a fire, replace plastic containers used to store shop rags with metal containers. The National Fire Protection Association (NFPA) recommends storing shop rags in metal containers with lids that are to be kept closed.[36]

A "No Smoking" policy should be implemented in the plant.[31] In addition to the health benefits, prohibiting smoking in work areas is an important fire prevention measure, particularly in the press department where flammable solvents are used extensively.

Dock workers should be reminded to allow bundles of fragrance inserts to air-out in the dock area (for at least a day) before being transported to the bindery department. Signs reminding workers

of this could be posted in the dock area. This matter should also be discussed during safety meetings and included in the employee training manual.

The design and performance of the local exhaust ventilation system serving the battery-charging process should be further evaluated by a qualified industrial ventilation engineer.

Housekeeping should be improved in the quality sample area by regularly removing paper dust on work surfaces. The preferred method for cleaning is using a vacuum cleaner with a high-efficiency particulate air (HEPA) filter. Using compressed air to remove dust is not be recommended.

Potential work-related symptoms should be reported to health care personnel. Health care personnel should work with WCP management to identify work areas and processes associated with specific health effects.

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Table 1
Air Sampling Results for Naphthas
World Color Press
Sampling Date: September 8, 1999

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (liters per minute)	Sample Volume (liters)	Concentration, milligrams per cubic meter (mg/m^3)
				Naphthas (petroleum)
Press #219 Operator	437	0.2	87.4	37
Press #228 Operator	391	0.2	78.2	41
Press #228 Operator	323	0.2	64.6	37
Press #228 Operator	413	0.2	82.6	27
Press #228 Operator	411	0.2	82.2	27
Press #231 Operator	393	0.2	78.6	17
Press #231 Operator	393	0.2	78.6	48
Press #231 Cleaner	294	0.2	58.8	24
Press #231 Cleaner	295	0.2	59.0	32
Press #231 Cleaner	295	0.2	59.0	98
Press #231 Cleaner	296	0.2	59.2	44
Area sample at Press #219	414	0.2	80.6	23
Area sample at Press #228	404	0.2	82.6	42
Area sample Outdoors	440	0.2	88	ND
Minimum Detectable Concentration (MDC)*				0.11
Minimum Quantifiable Concentration (MQC)*				0.55
Exposure Criteria (expressed in milligrams per cubic meter)				
NIOSH Recommended Exposure Limit (REL)				350
OSHA Permissible Exposure Limit (PEL)				2000
ACGIH Threshold Limit Value (TLV®)				none

Abbreviations:
* = assuming a 87.4 liter sample
ND = none detected (concentration below the MDC)

Table 2
Air Sampling Results for Naphthas
World Color Press
Sampling Date: September 9, 1999

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (liters per minute)	Sample Volume (liters)	Concentration, milligrams per cubic meter (mg/m^3)
				Naphthas (petroleum)
Press #219 Operator	436	0.2	87.2	18
Press #219 Operator	373	0.2	74.6	26
Press #226 Operator	453	0.2	90.6	24
Press #231 Operator	296	0.2	89.4	31
Area sample at Press #227	424	0.2	84.8	40
Minimum Detectable Concentration (MDC)*				0.11
Minimum Quantifiable Concentration (MQC)*				0.55
Exposure Criteria (expressed in milligrams per cubic meter)				
NIOSH Recommended Exposure Limit (REL)				350
OSHA Permissible Exposure Limit (PEL)				2000
ACGIH Threshold Limit Value (TLV®)				none

* = assuming a 90.6 liter sample

Table 3
Air Sampling Results for Aldehydes
World Color Press
Sampling Date: September 8, 1999

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (liters per minute)	Sample Volume (liters)	Concentration, parts per million (ppm)		
				formaldehyde	butanal	acetaldehyde
Press #231 Operator	425	1	425	0.020	0.003	0.019
Press #231 Operator	420	1	420	0.027	0.004	0.029
Press #227 Operator	443	1	443	0.016	0.003	0.016
Press #226 Operator	434	1	434	0.016	0.003	0.014
Press #226 Operator	436	1	436	0.016	0.003	0.016
Press #226 Operator	434	1	434	0.016	0.002	0.012
Press #227 Operator	443	1	443	0.013	0.002	0.013
Premelter #263 Operator	387	1	387	0.017	0.002	0.016
Area sample at Press #227	442	1	442	0.016	0.002	0.013
Area sample at Press #226	442	1	442	0.016	0.002	0.009
Area sample at Premelter #263	379	1	379	0.017	0.002	0.014
Area sample at Premelter #264	379	1	379	0.011	0.001	0.013
Area sample Outdoors	319	1	319	0.003	0.0003	0.002
Minimum Detectable Concentration (MDC)*				0.00002	0.00002	0.0006
Minimum Quantifiable Concentration (MQC)*				0.0007	0.0007	0.0002
Exposure Criteria (expressed in parts per million)						
NIOSH Recommended Exposure Limit (REL)				LFC (0.016)	LFC	LFC
OSHA Permissible Exposure Limit (PEL)				0.75	none	200
ACGIH Threshold Limit Value (TLV®)				0.30	none	25 (C)
AIHA Workplace Environmental Exposure Level (WEEL)				none	25	none

Abbreviations:
* = assuming a 443 liter sample
LFC = lowest feasible concentration
C = ceiling limit

Table 4
Air Sampling Results for Aldehydes
World Color Press
Sampling Date: September 9, 1999

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (liters per minute)	Sample Volume (liters)	Concentration, parts per million (ppm)		
				formaldehyde	butanal	acetaldehyde
Press #226 Operator	445	1	445	0.011	0.002	0.011
Press #227 Operator	437	1	437	0.013	0.002	0.014
Press #231 Operator	442	1	442	0.022	0.002	0.016
Press #226 Operator	451	1	451	0.011	0.002	0.01
Area sample at Press #231	425	1	425	0.014	0.003	0.012
Area sample at Press #227	424	1	424	0.009	0.002	0.009
Area sample at Press #231	404	1	404	0.013	0.002	0.010
Area sample at Press #228	373	1	373	0.013	0.003	0.009
Area sample at Hot-melt pot #264	430	1	430	0.023	0.007	0.127
Area sample at Premelter #263	445	1	445	0.011	0.002	0.012
Area sample at Premelter #264	430	1	430	0.005	0.005	0.168
Area sample Outdoors	431	1	431	0.001	0.0007	0.0006
Minimum Detectable Concentration (MDC)*				0.00002	0.00002	0.00006
Minimum Quantifiable Concentration (MQC)*				0.0007	0.0007	0.0002
Exposure Criteria (expressed in parts per million)						
NIOSH Recommended Exposure Limit (REL)				LFC (0.016)	LFC	LFC
OSHA Permissible Exposure Limit (PEL)				0.75	none	200
ACGIH Threshold Limit Value (TLV®)				0.30 (C)	none	25 (C)
AIHA Workplace Environmental Exposure Level (WEEL)				none	25	none

Abbreviations:
* = assuming a 451 liter sample
C = ceiling limit
Formaldehyde: 1 ppm = 1.23 mg/m^3
Butanal: 1 ppm = 2.95 mg/m^3
Acetaldehyde: 1 ppm = 1.80 mg/m^3

Table 5
Air Sampling Results for Resin Acids
World Color Press
Sampling Date: September 8, 1999

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (liters per minute)	Sample Volume (liters)	Concentration, micrograms per cubic meter ($\mu g/m^3$)	
				Abietic Acid	Dehydroabietic Acid
PBZ – Printing Press #226	434	2	868	trace	2
PBZ – Printing Press #226	434	2	868	trace	1.4
PBZ – Printing Press #226	438	2	876	ND	0.8
Area – Printing Press #226	442	2	884	4.5	9.2
PBZ – Printing Press #227	442	2	884	trace	0.8
PBZ – Printing Press #227	443	2	886	trace	1.2
Area – Printing Press #227	442	2	884	0.8	2.1
PBZ – Printing Press #231	420	2	840	trace	0.8
PBZ – Printing Press #231	425	2	850	ND	0.5
Area – Bindery #263	381	2	762	ND	1.2
PBZ – Bindery #263	387	2	774	ND	1.9
Area – Bindery #264	379	2	758	ND	3.3
Minimum Detectable Concentration (MDC)*				0.2	0.07
Minimum Quantifiable Concentration (MQC)*				0.7	0.2
Exposure Criteria (expressed in micrograms per cubic meter)					
NIOSH Recommended Exposure Limit (REL)				none	none
OSHA Permissible Exposure Limit (PEL)				none	none
ACGIH Threshold Limit Value (TLV)®				†	†

Abbreviations:
PBZ = personal breathing-zone
ND = none detected (concentration less than the MDC)
trace = concentration is between the MDC and MQC
* = assuming a 886 liter sample
† = reduce exposure as low as possible, as rosin

Table 6
Air Sampling Results for Resin Acids
World Color Press
Sample Date: September 9, 1999

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (liters per minute)	Sample Volume (liters)	Concentration, micrograms per cubic meter ($\mu g/m^3$)	
				Abietic Acid	Dehydroabietic Acid
PBZ – Printing Press #219	373	2	746	ND	0.5
PBZ – Printing Press #226	451	2	902	ND	1.1
PBZ – Printing Press #226	490	2	980	ND	1
PBZ – Printing Press #227	437	2	874	ND	0.3
Area – Printing Press #227	424	2	848	1.1	2.7
Area – Printing Press #228	421	2	842	ND	0.5
PBZ – Printing Press #231	442	2	884	ND	0.9
Area – Printing Press #231	404	2	808	1.4	7.8
Area – Printing Press #231	425	2	850	trace	1.1
Area – Bindery #263	445	2	890	ND	1.8
Area – Bindery #264	430	2	860	2.7	47
Area – Bindery #264	451	2	902	0.64	77
Minimum Detectable Concentration (MDC)*				0.2	0.07
Minimum Quantifiable Concentration (MDQ)*				0.7	0.2
Exposure Criteria					
NIOSH Recommended Exposure Limit (REL)				none	none
OSHA Permissible Exposure Limit (PEL)				none	none
ACGIH Threshold Limit Value (TLV)®				†	†

Abbreviations:
PBZ = personal breathing-zone
ND = none detected (concentration less than the MDC)
trace = concentration between the MDC and MQC
* = assuming a 980 liter sample
† = reduce exposure to as low as possible, as rosin

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