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COCALICO SCHOOL DISTRICT
DENVER, PENNSYLVANIA

NIOSH INVESTIGATOR:
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SUMMARY

On February 13, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the Cocalico School District of Denver, Pennsylvania. Representatives of the school district expressed concern that the source of a "solvent" odor in the Adamstown Elementary building was affecting the health of occupants. The suspected source of the odor was an organic solvent used to remove tile mastic during renovation of the building.

An industrial hygiene survey was conducted on February 21 and 22, 1991. Twelve area air samples were collected to measure the concentrations of volatile organic compounds in various locations of the building. Based on qualitative analytical results, concentrations of toluene, xylene, limonene, and total remaining aromatics were subsequently measured.

The air concentrations of individual compounds were well below existing occupational exposure guidelines. The concentrations of total VOCs in two of the twelve areas were in the range which may cause irritation of occupants (3 - 25 mg/m^3).

The source of the VOCs measured did not appear to be the solvent used to remove the tile mastic. Rather, they appear to be from products used in the construction and renovation efforts on-going during the collection of the air samples. This conclusion is based on a comparison between the analytical pattern of the air samples with that of the mastic remover and an in-house laboratory standard.

The concentration of individual VOCs measured on the day of the survey did not represent a health hazard. However, the concentration of total VOCs were in the range which may cause occupants to experience symptoms of eye nose and throat irritation. Recommendations to prevent elevated levels of VOC following future renovation efforts are provided.

KEYWORDS: SIC 1542 (Building repairs, nonresidential-general contractors), mastic remover, volatile organic compounds, VOCs, mastic, floor tile, indoor air quality, asbestos.

INTRODUCTION

On February 13, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the Cocalico School District of Denver, Pennsylvania. Representatives of the school district expressed concern that the source of a "solvent" odor in the Adamstown Elementary building was affecting the health of occupants. The suspected source of the odor was an organic solvent used to remove floor tile mastic during the removal of asbestos-containing floor tiles from schoolrooms.

On February 22, 1991, air samples were collected by the NIOSH investigator to determine if the airborne contaminants inside the building presented a health hazard. A letter summarizing the results of the samples was sent to the Director of the Building and Grounds for Cocalico School District on February 27, 1991. This letter reported that the air concentrations of chemical contaminants were very low, and that there was no information at that time which warranted continued closure of the school. Classes were resumed at Adamstown Elementary on March 4, 1991.

BACKGROUND

The Adamstown Elementary building is a one story brick structure located in Adamstown, Pennsylvania. Approximately 150 students in Kindergarten through fifth grade attend the school. There is a total of 22 staff members consisting of teachers, administrative personnel, and food service employees.

Asbestos-containing floor tile was removed from several schoolrooms because of the district's concern that friable asbestos would be generated during scheduled renovation efforts. The removal of the tile was performed in two stages. Tile was removed from some of the rooms between November 21 to November 26, 1990, during the Thanksgiving break (stage 1). Following the removal of the tile, an organic solvent was used to remove the tile adhesive or "mastic." The solvent was reportedly comprised primarily of terpenes which are VOCs containing 10 carbon atoms.[1]

Upon returning to school, staff and students complained of a strong odor in the building, and reportedly began to experience health symptoms. These symptoms included eye and throat irritation, nausea, and headaches. Remedial efforts taken at that time by the school district included the cleaning of floor surfaces with water, industrial strength cleaners, and high pressure mist deodorizers; and passively ventilating the building by leaving the windows open during the day and night. These efforts were reported to be marginally successful at reducing the odors. Prior to removing the tile from the remaining rooms (stage 2), precautions were taken in an attempt to prevent further odor and health problems. Emphasis was placed on supervision of the removal process, including the amount of solvent used, and the clean-up following removal. Stage 2 of the removal process was completed during the Christmas break, (December 26, 1990 to January 1, 1991).

Despite these precautions, the odor problem was reportedly worse after the second stage of tile removal. The odor was reported to permeate throughout most of the building at that time. Community organizations, parents and school staff expressed concerns that exposures at the school were causing health problems for the occupants. On January 7, 1991, the school district relocated the students to a local church as an interim solution while a more in-depth investigation of the problem was performed.

An extensive clean-up and remediation effort was initiated in early January 1991. This included the daily cleaning of floors and ventilation of the building. In addition, propane heaters were used in an attempt to increase the vaporization of the solvent, and ion and ozone air purification systems were also tried. Because the mastic remover was suspected to have been absorbed by materials located in the floor joints, a caulking sealant was eventually applied to this space.

After several weeks of remediation efforts, school district personnel began to observe a slight reduction in odors in various locations in the school. On February 13, 1991, the school district requested that NIOSH investigate the problem to determine if a health hazard existed in the building.

METHODS

Air samples were collected for qualitative and quantitative analysis of volatile organic compounds (VOCs). Area air samples were collected from twelve locations inside the school, and one location outside. Sample air was drawn through charcoal tubes using battery operated pumps; the sampling location and air volume of each sample is provided in Table 1. The charcoal tubes were analyzed for volatile organic compounds using gas chromatography (NIOSH Method 1501). Three air samples, and one bulk sample of the mastic remover, were collected for qualitative analysis. Based on the qualitative results, limonene, toluene, and xylene were quantified as individual compounds. The remaining VOCs detected in the air samples, consisted of aromatic hydrocarbons which ranged in molecular weight from 120 to 148. These compounds were quantified together, using a laboratory standard consisting of comparable compounds. The mixture of remaining aromatic hydrocarbons measured in the air samples is referred to as the "remaining aromatic fraction" in this report.

EVALUATION CRITERIA

General

As a guide to the evaluation of the hazards posed by work place 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 if 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 work place exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled to the level set by the evaluation criterion. These combined effects are not often considered by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase 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 work place are: 1) NIOSH Criteria Documents and Recommended Exposure Limits (RELs), 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S.

Department of Labor (OSHA) Permissible Exposure Limits (PELs). The OSHA PELs may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended exposure limits, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an 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 short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high, short-term exposures.

Terpenes

Evaluation criteria do not currently exist for the individual species of terpenes present in the solvent. Turpentine, a mixture of terpenes, has a NIOSH REL, OSHA PEL, and ACGIH TLV of 560 milligrams per cubic meter (mg/m^3). It is considered a skin and mucous membrane irritant and central nervous system (CNS) depressant.[2] Nose and throat irritation has been noted in human subjects exposed to concentrations of approximately 420 mg/m^3 for 3 to 5 minutes.[3]

Toluene

Toluene is a CNS depressant. Controlled exposure of test subjects to 750 mg/m^3 for 8 hours produced weakness, mild fatigue, lacrimation, confusion, and paresthesia of the skin. Exposure to 2250 mg/m^3 for 8 hours caused headaches, euphoria, dizziness, dilated pupils and nausea.[4] Irritation of the eyes and nose, headaches, dizziness, and a feeling of intoxication have been reported in test subjects exposed to 375 mg/m^3 for 6 hours.[5] The NIOSH REL, OSHA PEL, and ACGIH TLV for toluene is 375 mg/m^3.

Xylene

Xylene is an irritant of the eyes, mucous membranes, and skin.[6] Though sensitivity to compounds varies between individuals, the majority of test subjects in a controlled study found 870 mg/m^3 to be irritating to the eyes and mucous membranes.[7] The NIOSH REL, OSHA PEL, and ACGIH TLV for xylene is 435 mg/m^3.

Remaining Aromatic Fraction

As described in the methods section of this report, the remaining aromatic fraction consisted of those VOCs, other than limonene, toluene and xylene, which were detected in the air samples. Occupational exposure guidelines do not currently exist for this mixture of compounds. The majority of this fraction was tetramethylbenzene isomers. Exposure guidelines do not exist for these compounds. It has been suggested that the exposure guideline for trimethylbenzene (TMB), a compound of similar chemical structure but lower molecular weight, may be an appropriate surrogate based on toxicity data.[8]

The evaluation criteria for TMB is based primarily on a study of workers exposed to a mixture of TMB isomers. The NIOSH REL, OSHA PEL, and ACGIH TLV for TMB is 125 mg/m^3. This guideline is intended to prevent workers from experiencing asthmatic bronchitis, as well as a number of CNS symptoms, including nervousness and anxiety.[9]

VOCs in non-industrial settings

The evaluation criteria above are derived from data collected during exposures of workers or test subjects to VOC concentrations which approximate those in industrial settings. The concentrations of VOCs measured in schools and other non-industrial settings are generally much lower. Despite the low concentrations, many researchers believe that the presence of VOCs can contribute to the health symptoms experienced by workers in non-industrial settings. Suggested explanations for this are provided by Girman.[10] Among these explanations is that the range in age and health status can be much greater in these settings than in the industrial workplace. Also, the exposures in the industrial workplace may be limited to a few compounds, whereas in some indoor environments, there can be exposure to low concentrations of many compounds. It is unclear how to best evaluate the exposure of individuals to mixtures of VOCs at low levels.

One approach to evaluating the exposure to mixtures of VOCs present in the environment, is to measure the total VOC fraction. Although established evaluation criteria for total VOCs do not currently exist, Molhave has suggested the following guidelines.[11]

Data at the right is taken from Table V of Molhave.[11] Irritation symptoms refer to eye, nose, and upper respiratory tract irritation.

These guidelines are based primarily on data from laboratory studies conducted by Molhave.[12] In these studies, test subjects were exposed to controlled concentrations of a VOC mixture consisting of 22 air pollutants normally found in Danish homes; the total VOC concentrations ranged from 5 to 25 mg/m^3.

VOC Concentration (mg/m^3)	Health Effects Expected
< 0.16	None
0.16 - 3	Irritation and discomfort possible if other exposures interact
3 - 25	Irritation and discomfort probable; headache possible if other exposures interact
> 25	Additional neurotoxic

RESULTS

The analysis of the bulk sample confirmed that the mastic remover used is comprised almost entirely of terpenes, including limonene, camphene, and isomers of pinene, and terpinene. The VOCs detected in the air samples however, did not match that of the mastic remover; indicating that the source of compounds measured was not the mastic remover. The only terpene detected in the air samples was limonene. The principle source of the limonene measured in the air samples is not believed to be the mastic remover. If the mastic remover was the source, one would expect to find other terpene components of the mastic remover, since the percent composition for the other terpenes is similar to that of limonene. Known sources of limonene in addition to the mastic remover include paint, adhesives, and detergents.[13] Other compounds detected in the samples included toluene, xylene, and various aromatic hydrocarbons made up primarily of tetramethylbenzene isomers; these compounds are not present in the mastic remover. Common sources of toluene and xylene include adhesives, wallpaper, caulking compounds, floor coverings, and cigarette smoke.[13] Tetramethylbenzene and its isomers are used as general solvents and chemical raw material.[8]

The indoor air concentrations of the remaining aromatic fraction ranged from below the limit of quantitation (LOQ) to 3.3 milligrams per cubic meter (mg/m3). Concentrations of limonene indoors ranged from 0.054 to 0.29 mg/m^3. These values are well below the occupational guidelines used in this investigation to evaluate VOC exposures. Table 1 summarizes the concentrations of limonene and the remaining aromatic fraction. The indoor air concentrations of toluene and xylene were below the LOQ. Concentrations ranged from 0.012 to 0.065 mg/m^3, and from non-detected (ND) to 0.050 mg/m^3, for toluene and xylene, respectively.

The greatest indoor concentrations of VOCs were in the reading room and the new kindergarten room. In addition to the compounds mentioned above, a mixture of hydrocarbons similar to mineral spirits or stoddard solvent was also detected in these two rooms. Mineral spirits is commonly used as a degreaser and paint thinner.[14]

Other than a low concentration of toluene (0.012 mg/m^3), VOCs were not detected in the outdoor air sample.

DISCUSSION

The VOCs measured in the air samples are constituents of products commonly used during construction and renovation efforts. Renovation and construction efforts were ongoing outside and in the reading and kindergarten rooms during the collection of air samples. The total VOC concentrations measured in these two rooms were in the range where occupants may be expected to experience irritation symptoms (3 - 25 mg/m^3), using the guidelines provided by Molhave.[11] This data demonstrates that renovation efforts may introduce contaminants into the occupied environment at concentrations which may cause irritation. For this reason, it is recommended that such efforts be done during periods when the building is not occupied.

The concentrations of VOCs measured during this investigation are not believed to represent a health hazard. However, it is prudent to reduce VOC exposures to minimize the potential for irritation symptoms and odor complaints. The school district has taken steps toward this goal. Odors from VOCs may persist if the compounds have been absorbed by porous surfaces such as office dividers, draperies, or even paper products. If there are particular locations where odors persist, sources of the odor will need to be cleaned or removed.

Although air concentrations of mastic remover constituents were not measured in the school, representatives of the school district were convinced that the mastic remover was the source of the odor following the tile removal. This association of occupant complaints with the use of chemicals to remove tile mastic, is not unique to Adamstown Elementary. NIOSH has investigated two other buildings where similar problems have reportedly been experienced by occupants.[15,16]

Remediation measures taken at Adamstown Elementary included increased ventilation, cleaning the floors with various products, the use of heat to hasten the vaporization of the solvent, and the use of ion and ozone generating purifiers as an attempt to reduce air contaminants. Ventilation of the building is generally an effective method of diluting contaminants levels inside. The addition of heat to a building to promote the vaporization of VOCs, is commonly referred to as a "bake-out" process. Although this process has been shown to be effective for some contaminants, there are several factors which need to be considered to provide the most effective use of temperatures and ventilation and prevent property damage.[10] Cleaning of the floors can be effective at reducing contaminants and is recommended by the distributor of the mastic remover following application. Keep in mind however, that cleaners often contain VOCs which can contribute to odor complaints. Scientific evidence supporting the use of ion and ozone generators to reduce VOC concentrations in indoor air settings is insufficient to recommended their use for this purpose.

A representative of the school district reported that the solvent penetrated into the floor joints, and was absorbed by porous materials located near the floor joints. The school district addressed the problem by sealing the space with a caulk. This essentially "traps" the solvent in the floor joint, which may have allowed vapors to make their way to other areas of the building. An understanding of the potential problems associated with using products containing VOCs is needed during an asbestos abatement project to prevent health and odor complaints. A potential problem specific to applying liquid products to floor surfaces, is the pooling of the liquid in floor joints and on top of damp-proof membranes. Floor joints can act as sinks for liquids, and removing the liquid can be more difficult if porous materials are present near the joints. Damp-proof membranes are incorporated into the structure of floors to prevent water and water vapor from entering the occupied zone from below. If liquid products are used during renovation, they are likely to pool above this membrane, creating a source of contamination. If a damp-proof membrane is not in place, the excess liquids may penetrate into the soil, where, depending on the chemical and soil interactions, may or may not act as a source of contamination for the occupied zone. Steps to prevent the contamination of surfaces are needed in the planning of the abatement project. It may be prudent for school districts to request evidence that such steps have been included in the work plan before giving approval for work to begin.

A plan for evaluating elevated concentrations of VOCs may include the monitoring of VOC concentrations before, during, and following renovation efforts. A comparison of air monitoring data before and after renovation could aid in assuring that VOC concentrations are not elevated, or identify contaminated areas that need to be cleaned up before the area is reoccupied. Assigning the responsibility of preventing elevated levels of VOCs to the contractor may help reduce their occurrence following renovation efforts. Air monitoring should be conducted by an independent contractor or consultant. If environmental monitoring is conducted for VOCs, the post-renovation samples should be collected after clean-up operations have ceased and building operations have returned to normal.

RECOMMENDATIONS

The following recommendations are provided to help prevent odor and health complaints from occurring in the future as a result of VOCs used during renovation efforts; this includes the use of chemicals to remove floor tile mastic.

1. Whenever possible, work should be restricted to periods when the building is not occupied. When this is not possible, work areas should be contained and thoroughly cleaned to prevent the contamination of occupied areas.

2. A plan to prevent elevated concentrations of VOCs following renovation efforts should be contractually specified. This should include prevention efforts such as inspecting the work area to identify potential problem areas which could act as sinks for liquid contaminants, ventilating the work area during the use of VOC products, and the protection of porous surfaces in the work area by using vapor barriers such as sealed plastic coverings.[13]

3. Remedial efforts for reducing elevated VOC concentrations should focus on ventilation of the contaminated area with outside air. Because of the potential for contaminating the porous surfaces which line the heating, ventilation, and air conditioning system (HVAC), and to prevent the distribution of contaminants in the building, it is recommended that HVAC systems not be operated during remedial efforts. If this is the only method of ventilating the area, porous surfaces lining the HVAC system should be protected by using a vapor barrier. Bake-out procedures may also be of use; however, these procedures should be supervised by individuals familiar with the process.

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Copies of this report have been sent to:

1) Director of Building and Grounds, Cocalico School District
2) Representative of the Cocalico Education Association
3) OSHA Region Three

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.

Table 1
Results of Air Sampling for Volatile Organic Compounds (VOCs)
Adamstown Elementary
HETA 91-0118
February 22, 1991

Sample location	sample volume (liters)	mg/m^3 limonene	mg/m^3 remaining aromatic fraction	mg/m^3 total VOCs
lobby	85	0.054	(0.39)	0.44
reading room	85	0.29	3.2	3.5
faculty room	86	0.12	1.2	1.3
main office	86	0.076	0.65	0.73
room 5	85	0.11	0.95	1.1
room 6	42	(0.05)	(0.46)	0.51
room 2	85	0.18	0.88	1.1
room 4	42	0.15	0.97	1.1
new kindergarten	38	0.20	3.3	3.5
guidance room	42	0.22	1.6	1.8
room 1	42	0.28	1.4	1.7
room 3	42	0.29	1.6	1.9
outside	85	ND	ND	ND
limit of detection		0.025	0.28	NA
limit of quantitation		0.083	0.93	NA
NIOSH REL		560+	125+	NA
OSHA PEL		560+	125+	NA
ACGIH TLV		560+	125+	NA

* The values for total VOCs are approximate concentrations calculated by summing the concentrations of limonene and the remaining aromatic fraction.

( ) The concentration of the sample is between the limit of detection (LOD) and the limit of quantitation (LOQ). The values for the LOD and LOQ provided in the table are for a 40 liter sample.

ND The concentration of the sample was below the limit of detection (LOD).

\+ Because evaluation criteria do not exist for limonene and the remaining aromatic fraction, those for turpentine and trimethylbenzene respectively, were used as surrogate evaluation criteria.