HETA 98-0300-2723
Dollar General Store
Prestonsburg, Kentucky

Max Kiefer

PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Max Kiefer of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS), Atlanta Field Office. Analytical support was provided by Ardith Grote and Elaine Matthews, DPSE. Desktop publishing was performed by Shantel Brown. Review and preparation for printing was performed by Penny Arthur.

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Health Hazard Evaluation Report 98-0300-2723
Dollar General Store
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SUMMARY

On August 7, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation (HHE) at the Dollar General Store in Prestonsburg, Kentucky. The request indicated that some employees at this facility had experienced health problems possibly related to their work environment. Reported health problems included headache, nausea, dizziness, and shortness of breath. Potential sources of contamination in the work area included mold growth from moisture damage, and volatile material from adhesives used in the floor tile. Of considerable concern to Dollar employees was a persistent "vomit-like" odor present in the store.

A NIOSH investigator conducted a site visit to the Dollar General Store on September 23-24, 1998. During the site visit, environmental samples were collected to characterize volatile compounds present in the facility and to determine the type and quantity of fungal and/or bacterial growth in various bulk samples. Measurements of standard indoor environmental quality (IEQ) parameters (Temperature [F°], relative humidity [%RH], and carbon dioxide [CO_2]) were monitored at various times throughout the day. The ventilation system supporting the facility was inspected. The described odor was present during the site visit.

All measured IEQ parameters were within acceptable guidelines as defined by the American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE). Sufficient outside air (OA) was being provided to occupied areas. Qualitative air samples for volatile compounds identified traces of butyric acid, which may be a contributor to the odor. The source of the butyric acid was not determined. Microbiological growth was found in some of the bulk samples, primarily from dust/debris collected underneath product display flats in the sales area. The organisms, consisting of mostly yeast, are consistent with those normally present in moist environments. A limited visual inspection of the ventilation system indicated the system was clean and operating properly. The interior duct work was not inspected. No source of contaminants were noted near the outdoor air intake vents of the air handling units. No visible signs of moisture damage or mold growth were observed.

Inspection of the sales floor, storage areas, and restrooms did not identify any obvious contaminants that could be attributable to the odor. Janitorial practices were standard and did not appear to be contributing to the problem odor. In some areas the floor tile was loose and cracked where the tile had not properly adhered to the concrete floor. Except for one discolored ceiling tile in the South East corner of the sales floor, there were no visible signs of moisture incursion or damage. Both the supply and return air (RA) is ducted to the ventilation system and the area above the false ceiling does not serve as a common air plenum. Inspection of the firewall separation between

the Dollar Store and the adjoining locations found no visible unsealed penetrations. The building pressure is positive with respect to outside which reduces the likelihood that externally generated contaminants are entering the store.

The chemical identity and specific source of the persistent "vomit-like" odor was not identified during the NIOSH investigation and the relationship between the odor and the reported health problems was not determined. Evaluation of activities, products, and building systems did not suggest an obvious IEQ problem. The building ventilation system was supplying sufficient OA to occupied areas and measured IEQ parameters were within acceptable ranges. No sources of contaminants were identified near the OA intakes on the ventilation system. There was no evidence of excessive microbial growth. Efforts to resolve the odor problem should continue. Recommendations to systematically identify and resolve potential sources of IEQ problems are provided.

Keywords: SIC 5331 (Variety Stores): Indoor Air Quality, IAQ, IEQ, "vomit-like" odor, dirty sock syndrome, ceiling tile, ventilation, nausea.

TABLE OF CONTENTS

INTRODUCTION

In response to a confidential employee request, a National Institute for Occupational Safety and Health (NIOSH) investigator conducted a site visit at the Dollar General Store in Prestonsburg, Kentucky, on September 23-24, 1998. The request was submitted after referral from the Kentucky Labor Cabinet, Department of Occupational Health and Safety. The request asked NIOSH to determine if health problems experienced by some store employees were related to their work environment. Specific health complaints listed on the request included headache, nausea, dizziness, itching eyes, runny nose, shortness of breath, and diarrhea. Suspected building contaminants, or sources of contaminants, identified on the request included mold growth resulting from water damage associated with a sprinkler system break, and possible uncured floor tile adhesive. A persistent "vomit-like" odor present in the sales area of the building was also identified as a specific concern.

During the site visit a meeting was held with employee and management representatives and a walkthrough inspection of the facility was conducted. Air and bulk samples were collected in an attempt to characterize the chemical nature of the odor. Additional bulk samples were obtained for microbiological analysis. Standard indoor environmental quality (IEQ) parameters (temperature, relative humidity [RH], carbon dioxide [CO_2]) were monitored. The ventilation system was inspected in conjunction with a maintenance operation to clean the ventilation system cooling coils.

BACKGROUND

The Dollar General Store in Prestonsburg, Kentucky, is located in a single-story strip mall that was constructed in the mid 1980's. The Dollar Store moved into the current location in October 1997; the location was vacant for approximately 6 years prior to occupancy by the Dollar Store. The store is adjoined by an unoccupied space on one side, and a college class room with offices on the other side. The store has an open-floor sales area of 6700 ft^2 and a stock room of approximately 1000 ft^2 that are separated by a firewall. Ceiling height is approximately 15 ft. There is a 3 foot drop-ceiling (ceiling tile with fluorescent light fixtures) in the retail sale area and no drop-ceiling in the stock room. The roof is flat, constructed of corrugated metal with steel trusses, and is contiguous with the roof of the adjoining businesses. The facility has a concrete block exterior with sheetrock walls on the inside. At the time of the NIOSH visit, six employees worked at the store, with 2-3 workers usually present on each work shift. These employees had been recently transferred (within 1-2 months) to this store.

When the store was first occupied in October 1997, there were no reports of IEQ problems or unusual odors. A new heating, ventilation, and air-conditioning (HVAC) system was installed approximately two weeks after the store was occupied, and reports of a persistent odor described as "vomit-like" began to be reported to Dollar management. Following these reports, the ductwork was inspected by the HVAC system installers, but no problems were noted. However, the odor persisted. In January 1998, some employees began reporting illnesses, including nausea, diarrhea, and shortness of breath, they associated with their work environment. Some employees sought medical attention, and several were advised by their physician not to work at this Dollar Store location. Some employees were transferred to other stores and the symptoms of some employees reportedly improved after they had been away from the building for 2-3 weeks.

In April 1998, Dollar contracted with an environmental consultant to investigate the odor problem and recommended appropriate remedial measures. The consultant collected a number of water samples, which were analyzed for pesticides, PCBs, total coliform, and metals. Bulk samples for bacteria and fungal growth were also collected. These results were inconclusive and the source of the odor was not determined. The consultant concluded that the odor and health problems were likely due to poor ventilation (no source of outside air [OA]) and inadequate moisture protection that resulted in the release of vapors from uncured floor tile in the store. The consultant recommended providing OA to the facility, improving the quality of the air filters in the HVAC intake, removal of all floor tiles where adhesive had not cured, and waterproofing the outside walls of the facility. At the time of the NIOSH visit, provisions to provide OA to the facility had been implemented. Although the consultant report noted that the odor had initially dissipated after implementation of the OA modification, reports of the odor continued at the Dollar Store. In May 1998, a sprinkler head in the stock room broke and the area was water damaged. Following this incident, Dollar employees and management were concerned about potential microbial growth from the water damage, and the area was cleaned. A site investigation was subsequently conducted by a representative from the Kentucky Labor Cabinet, Department of Occupational Health and Safety, but no obvious IEQ problems were identified. In another attempt to resolve the problem, the ceiling tile was replaced in mid-August 1998. When the original ceiling tile was removed the problem initially appeared to be resolved. However, the odor returned within 4-5 days after the new tile was installed.

EVALUATION METHODS

Thermal Desorption (TD) Tube Sampling

On September 24, 1998, four area air samples were obtained utilizing reusable Carbotrap® 300 multi-bed thermal desorption (TD) tubes as collection media. These tubes are designed to trap a wide range of organic compounds for subsequent qualitative analysis via thermal desorption and gas chromatography/mass selective detector (GC/MSD). Each stainless steel tube contained three beds of sorbent material. Samples were collected in two areas in the main store room and in the adjoining stock room. An outside (behind the store) sample was collected for control, or comparison, purposes. Two blank samples were provided for quality control. This sampling was conducted to help determine the chemical identity of the odor present in the work environment. Because the persistent odor was more noticeable in the main store room, and absent in the stock room, a comparison of the results from these areas could potentially identify the offending contaminant.

Low-flow air sampling pumps (SKC Pocket Pump™) were used to collect the air samples. Flow rates of 50 cubic centimeters per minute (cc/min) and sample times of approximately 240 minutes resulted in total sample volumes of about 12 liters of air. The SKC model Pocket Pump™ is a constant-flow sampling pump that was pre- and post-calibrated using a primary standard (BIOS® Dry Cell) to verify the flow rate. The total volume of air sampled is the product of flow rate and time sampled.

After collection, the samples were shipped via overnight delivery to the NIOSH laboratory for analysis. At the NIOSH laboratory, each sample was analyzed by directly inserting the tube into a thermal desorber unit (Perkin Elmer ATD 400 thermal desorption system) with no other sample preparation. A desorption time of 10 minutes at 300°C was used. The thermal desorber was directly connected to the GC and MSD. Reconstructed total ion chromatograms were obtained for each sample, and all were scaled the same for comparison. Each peak in the chromatogram was identified.

Bulk Sample

In an effort to identify the source of the odor, a sample of ceiling tile was obtained and shipped to the NIOSH laboratory for analysis. After collection, the sample was sealed in a plastic bag (double-bagged) prior to shipment. At the NIOSH laboratory, several headspace samples were collected inside the plastic bag containing the ceiling tile using thermal desorption tubes (described in previous section). Additionally, a portion of the ceiling tile was heated directly in the automatic thermal desorption system at 60°C and analyzed as described above.

Microbial Sampling

Because water damage from a previous fire sprinkler system leak in the Dollar Store was considered a potential source of microbial growth, six bulk samples were collected for microbiological analysis. A bulk sample of sheet rock from between the stock room (where the sprinkler system leak occurred) and sales floor was collected, as well as a sample of ceiling tile. Four samples of dust/dirt from the sales floor (under product flats, or under loose floor tile) were also obtained. After collection, the samples were sealed in labeled 150 milliliter (ml) polyethylene containers and shipped via overnight delivery to the NIOSH contract microbiological laboratory (P&K Microbiology Services, Inc., Cherry Hill, New J). At P&K, a portion of each sample was cultured for mesophilic bacteria with species identification (top 3 species) and total colony count at 25°C using tryptic soy agar. A portion of each sample was cultured for fungal species using 2% malt extract agar.

Indoor Environmental Quality

Carbon Dioxide (CO_2)

Instantaneous measurements of (CO_2) concentrations were obtained using a portable (direct-reading) Metrosonics aq-5000 Indoor Air Quality (IAQ) Monitor with a digital readout. The principle of detection is non-dispersive infrared absorption; the monitor contains an infrared sensor that requires air to be drawn through it by means of a battery-operated sample pump. The instrument was zeroed (zero CO_2 gas source) and calibrated with a known CO_2 source (span gas) prior to use. The monitor has a response time of approximately 60 seconds, and a resolution of 1 part per million (ppm) up to 10,000 ppm CO_2. Measurements were periodically obtained throughout the store and outside (for comparison) on September 23 and 24, 1998.

Temperature and Relative Humidity (RH)

Dry bulb temperatures and relative humidity (%RH) levels were obtained at the same times and locations as the CO_2 readings. The same instrument was used for the measurements as the Metrosonics aq-5000 monitor contains an RH and temperature sensor built in to the sampling wand. RH is determined by a capacitive sensor and a thermistor is used for the temperature measurements. The RH sensor can resolve to 0.1% RH with a response time of approximately 50 seconds (range 0 to 100%). The temperature thermistor can resolve to 0.1°C with an accuracy of 0.5°C and a range of 0 to 60°C. Both sensors had been factory calibrated prior to use.

Building Pressure

Building pressure was qualitatively determined using smoke tubes (MSA, Inc.) and a hand-held squeeze bulb. Doors (between the stock room and the sales floor, stock room and outside, and the sales floor and outside) were opened approximately 1 inch and the generated smoke was observed to determine airflow direction between the two spaces. Tests were repeated from the opposite side of the door to verify results. Smoke was also generated at penetrations (conduit, sprinkler pipe) between the stock room and the sales floor to determine airflow direction.

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, 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 workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[1] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[2] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[3] NIOSH encourages employers to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard.

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 (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Specific evaluation criteria, including health hazard information and recommendations are provided in *Appendix A* (Indoor Environmental Quality) and *Appendix B* (Microbial Contaminants and HVAC Systems).

RESULTS

Observations

During the site visit, an odor that could be described as "vomit-like" was present in the sales area of the Dollar Store. As perceived by the NIOSH investigator, the odor appeared to be uniformly detectable throughout the sales floor, and did not seem to be concentrated in any specific area. The odor was faint to non-detectable in the stock room. During the walkthrough of the adjacent businesses, the NIOSH investigator did not detect a similar odor. Dollar management was aware of the odor and had taken a number of steps (replacing the ceiling tile, HVAC maintenance, etc.) in an attempt to resolve the problem. Informal discussions with employees indicated some workers were concerned that continuous exposure to the odor may cause adverse health problems.

Inspection of the sales floor, storage areas, and restrooms did not identify any obvious contaminants that could be attributable to the odor. Although some of the merchandise (pesticides, cleaners, etc.) contain odorous constituents, there was no evidence of leaking or unsealed containers and this is not considered a likely source. New lighting fixtures and ceiling tile had recently been installed in the sales area. The stock room was cluttered and contained boxes of merchandise stored in a manner such that access in this area was difficult. This area also serves as a breakroom for employees. No obvious signs of moisture damage or water leaks were noted in this area. Although a floor-to-ceiling wall exists between the sales floor and the stock room, penetrations (ductwork, conduit, support beams) between the two spaces were not sealed. Smoking is permitted in the stock room. Janitorial practices were standard and did not appear to be contributing to the problem odor. In some areas the floor tile was loose and cracked where the tile had not properly adhered to the concrete floor. Except for one discolored ceiling tile in the South East corner of the sales floor there were no visible signs of moisture incursion or damage.

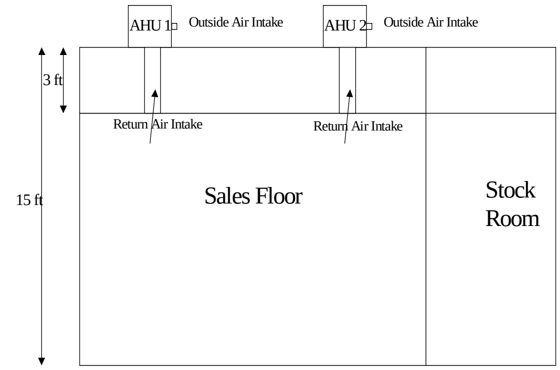
The area above the false ceiling (approximately 3 feet between the bottom of the roof and the false ceiling) is not insulated. Both the supply and return air (RA) is ducted to the ventilation system and the area above the false ceiling does not serve as a common air plenum. Inspection of the firewall separation between the Dollar Store and the adjoining locations found no visible unsealed penetrations.

Building Ventilation

Ventilation to both the sales area and stock room (Figure 1) is provided by two package rooftop air handling units (AHUs). Supply air (SA) is provided to the sales area and stock room via ceiling level diffusers. OA is obtained from intakes mounted on the side of each AHU. Intake grilles (one per AHU) located in the ceiling of the sales area are connected by ductwork to the AHUs and serve to convey RA back to each unit. The mixed air (RA & OA) passes through filters and then the cooling coils or heaters prior to being distributed to occupied areas. OA dampers are controlled by economizers designed to allow more OA into the system if outside conditions are favorable, and less if conditions are unfavorable.

The interior of the supply ductwork was not accessible and was not inspected. Dollar representatives indicated the interior of the ductwork is not lined. The two rooftop AHUs were clean and the filters had been recently replaced. Condensate pans appeared to be draining properly and there was no standing water in the pans. One of the condensate drain pan PVC pipes was broken, and water was discharging away from the roof drain. There was no obvious source of contaminants near the OA intakes. During the AHU inspection, contract ventilation maintenance was being conducted that included cleaning the coils with an acid-based cleaner followed by treatment with a commercially available encapsulant. (1st Strike MicroCoat®, Controlled Release Technologies). This work was being

Figure 1: Dollar General Store, Prestonsburg, Kentucky

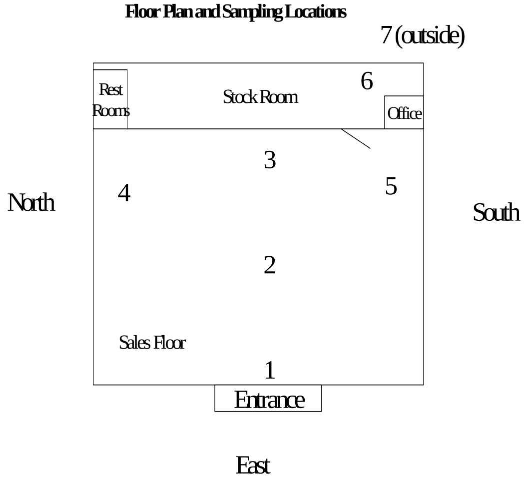


conducted in an effort to resolve the odor problem experienced inside the store. The product being applied was specifically marketed for HVAC odor problems. The contract HVAC maintenance workers and the supporting engineer indicated they were aware of similar odor problems occurring in both residential and commercial ventilation systems. These individuals attributed the problem, described as "dirty sock syndrome" to a phenomena that occurs with the cooling coils under certain conditions of heat or cooling load and humidity. No other explanations were offered.

Temperature, Relative Humidity (RH), and Carbon Dioxide (CO_2)

The results of the temperature, RH, and CO_2 measurements are shown in Table 2. The sampling locations and floor plan of the Dollar Store are depicted in Figure 2. On both days sampled, outdoor conditions were optimum (clear, cloudless day). On September 23rd, there were 14-15 people inside the store and between 10-12 people were present during the monitoring on September 24th. On September 24, all measured temperatures were below the American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) recommended range (Appendix A, Figure 1). At the time of this monitoring, the AHU fan was supplying filtered, but otherwise unconditioned (no heating) air to the occupied areas. Adjustments to the AHUs were being made on a periodic basis in an attempt to resolve the odor problem. RH levels in all occupied areas were within acceptable ranges. The CO_2 concentrations in all areas were well below both the 1000 ppm ASHRAE guideline and the proposed guideline of 800 ppm.[4,5]

Figure 2: Dollar General Store, Prestonsburg Kentucky. Floor Plan and Sampling Locations



1-7: Sampling Locations for temperature, relative humidity and carbon dioxide measurements

Building Pressure

Observation of visible smoke generated at doors and penetrations indicated the Dollar Store has a positive pressure with respect to outside (air flow direction is from inside the store to outside at both the front and back door). Additionally, the stock room is positive with respect to the sales floor (air flow direction is from the stock room to the sales area at the door between the two spaces, or through unsealed penetrations with the door closed).

Thermal Desorption (TD) Tube Sampling

Four-hour air samples for qualitative analysis were collected on September 24. Two samples were collected from the sales floor (front and back center), one sample from the stock room, and one sample was collected outside behind the mall. Because the sampling and analysis was qualitative, concentrations were not determined, although the chromatograms were scaled the same for comparison. All of the indoor samples displayed low levels of volatile organic compounds (VOCs), which is a typical finding in indoor settings. Major compounds detected in the field samples included propane, isobutane, butane, ethanol, acetone, isopropanol, butyl cellosolve, ethyl acetate, toluene, limonene, p-dichlorobenzene, siloxanes, and naphthalene. The likely source for many of these compounds are from products present in the store. Relatively few compounds were detected in the outdoor sample. There was little appreciable difference between the samples in the sales floor and the sample collected in the stock room. The chromatograms from the sales floor and the stock room were very similar in both the compounds detected and the relative intensity (relative concentration) of the peak.

A previous report of an investigation of "vomit-like" odors at a government facility in Massachusetts indicated that butyric acid may have been responsible.[6] As such, at the NIOSH laboratory, emphasis was placed on identifying any butyric acid in the samples. Traces of butyric acid, acetic acid, and propanoic acid were identified on all samples collected inside the Dollar Store. The chromatograms suggest that the relative concentration of butyric acid in the sales area was greater than the concentration detected in the stock room.

Headspace air samples using thermal desorption tubes were collected in the plastic bag containing the ceiling tile sample. Sampling was conducted for 20 minutes, 70 minutes, and 120 minutes at a flow rate of 100 cc/min. As the sample was "double-bagged," a sample was also collected inside the emptied "outer" bag. Compounds found in the samples included methanol, acetic acid, propanoic acid, butyric acid, butyl cellosolve, toluene, siloxanes, naphthalene, and aliphatic hydrocarbons and aldehydes. The chromatograms from the headspace sampling showed many of the same compounds as that found in the other air samples, although the relative intensity of the signals were different. For example, the relative concentration of butyric acid in the headspace sample appeared to be higher than that in the other air samples, while the butyl cellosolve concentration in the air sample appeared to be much higher than the headspace sample. A portion of the ceiling tile was also heated directly in the thermal desorber. Only one compound (bis [dimethylethyl] ethyl phenol) was detected on this sample.

Microbial Sampling

The results of the bulk microbial sampling are shown in Table 2. The results are reported in total colony counts and concentration (colony forming units per gram sample [CFU/g]), and the percentage of each group of fungi or bacteria present in the total population detected. Fungal levels in the bulk samples ranged from <481 CFU/g (below the limit of detection [LOD]) to 204,412 CFU/g. Bacterial levels ranged from below the LOD (719 CFU/g) to 12, 288,210 CFU/g. No fungal growth was detected on the sheetrock sample (obtained from the stock room wall) or the ceiling tile (obtained from tile at entrance to the bathroom). Fungal and bacterial growth was detected in samples consisting of broken floor tile and dirt/debris, and in samples of accumulated dust obtained from under the product display flats. The fungal organisms detected are commonly found in outdoor and indoor environments where there is sufficient moisture present. The dominant species of bacteria found in the samples are also identified in Table 2, and the total colony count is provided. The *Oerskovia* and *Cellumonas* species are gram positive organisms commonly found in soil. The *Citrobactor* and *Comamonas* are gram negative organisms that generally requires moisture to survive.

DISCUSSION

Odors figure prominently in IEQ complaints, have historically guided ventilation practice, and are often used to make judgements on the healthfulness of indoor spaces.[7] Even though it may be difficult to link an unpleasant odor and illness, the presence of objectionable odors connotes an unhealthful environment. For example, one study found that persons exposed to unpleasant odors may feel these odors adversely affect their health, mood, and performance.[8] Although the sense of smell should not be relied on to evaluate workplace hazards, odor can be a helpful guide in a building investigation. Inappropriate odors in the environment are unwanted, may be repulsive to some, and may be difficult to tolerate. Resolution of odor problems is an important aspect of maintaining good IEQ.

Anecdotal information regarding similar odor problems in non-industrial workplaces is available. For example, an Internet web site (Dirty Socks Syndrome) and Listserve has been established to both provide and solicit information regarding this phenomenon. Although supporting data is not provided, information on this web site indicates that the odor may be due to fungal growth on heat pump coils.[9] At the previously discussed government facility in Massachusetts, the source of the "vomit-like" odor was attributed to butyric acid generated from a fermentation reaction with binding agents in ceiling tile.[6] The investigator's explanation was that excessive moisture from unconditioned OA entered into the plenum space above the false ceiling and reacted with the binding agents. These were not the conditions present at the Dollar Store.

Odor descriptions and thresholds from tests conducted with panels have been published.[10,11] Both descriptions and threshold levels for odorants are subjective as sensory detection, perceived intensity, recognition thresholds, and judgement on the relative pleasantness or unpleasantness of the odor will vary among individuals.[11] A number of compounds have non-specific odor descriptions such as disagreeable, foul, sickening, repulsive, nauseating, unpleasant, etc., with no further descriptive information, thus complicating investigations to determine the chemical nature of an odor.[10,11] One published source characterizes butyric acid as having a sour, or perspiration-like odor with an odor threshold of

0.001 milligram per cubic meter of air.[10] The odor present at the Dollar Store could fit this, and other, descriptions.

During the site visit, the HVAC system was supplying sufficient OA to occupied areas and measured IEQ parameters were within acceptable ranges. No sources of contaminants were identified near the OA intakes on the ventilation system. Observation of visible smoke to evaluate building pressure indicated the store is positive with respect to outside. Thus, contaminants generated outside the Dollar Store would not flow into the store and are not a likely source for the odor. This is a desirable operating mode.

Odors from microbial VOCs (volatile contaminants from bacterial or fungal growth) can occur.[12] A common odor from this source is the musty, mildew-like odor that can be produced by a number of fungi. Although the data on VOC production from microorganisms is somewhat sparse, and odor descriptions are subjective, a review of fungal odor characterizations did not identify any that were described as "vomit-like".[12] This information, developed from both experimental results and a literature review, placed fungal odors into five categories with the following descriptions: (1) Musty, paper-like, mildew like. (2) Fress mushroom-like mustiness. (3) Obnoxious, heavy, cat-like mustiness. (4) Jute sack-like mustiness, and (5) Snow pea pod-like mustiness.[12] During the site visit, no obvious signs of water damage or microbial growth were found. The bulk samples collected during this survey identified organisms that are commonly found in the environment and do not suggest that additional investigation to evaluate potential exposure to microbial contaminants is warranted. However, housekeeping improvements are warranted to ensure that dust/debris, which is a potential reservoir, is controlled. Because the odor was present prior to the sprinkler failure, it does not appear that this incident, or microbial growth from water damaged material, are likely explanations for the odor.

The presence of butyric acid in the air samples is suggestive, but not conclusive. The results do indicate that perhaps this, or related compounds, may be contributing to the odor. However, this compound was specifically looked for in the sample and the prevalence of butyric acid as a background constituent in indoor air in non-problem buildings is not known. Although butyric acid was detected in the headspace of the ceiling tile, it is not known if the ceiling tile was the source or served as a sink for a contaminant generated elsewhere.

CONCLUSIONS

The chemical identity and specific source of the persistent "vomit-like" odor was not identified during the NIOSH investigation and the relationship between the odor and the reported health problems was not determined. Although there appears to be a number of anecdotal case reports of "vomit-like"or "dirty-sock" odors in both residential and commercial settings, a review of the literature did not identify any documented instances, or validated explanations for this occurrence. The building HVAC system was supplying sufficient OA to occupied areas and measured IEQ parameters were within acceptable ranges. No sources of contaminants were identified near the OA intakes on the ventilation system. There was no evidence of excessive microbial growth that could be associated with the odor problem. Efforts to resolve the odor problem should continue. A systematic approach to identify and resolve potential sources of IEQ problems should be implemented.

RECOMMENDATIONS

Eliminating the odor problem should remain a priority. Because the chemical identity and source of the odor was not identified during this survey, a "solutions-oriented" approach is recommended. This is a common course of action in many IEQ investigations where an environmental explanation has not been identified. This approach involves a systematic cycle of hypothesis generation and testing. As questions or plausible causes are suggested, they should be considered, evaluated, and addressed. This serves to narrow down the possibilities as potential explanations are ruled out, or improvements are implemented. The problems may be multifactorial in nature, with contributions from a number of potential causes. The recommendations in this report are intended to resolve potential or hypothesized causes of the odor problem, and not because of specific deficiencies that were identified during the NIOSH site visit.

At the Dollar Store, the following actions are recommended:

1. Continue to work with the HVAC manufacturer and service provider and implement modifications that may impact the odor problem. These include the planned replacement of the existing cooling coil system. Additionally, an experienced ventilation firm should be utilized to conduct a complete inspection of the HVAC system, including the interior of the supply and RA ducts. The integrity of the pressurized components of the system (coils, evaporator) should be verified. Any identified problems should be corrected. Repair the broken condensate drain pipe.

2. Although replacement of the ceiling tile had been unsuccessful in resolving the odor problem, Dollar personnel reported that the odor was not present during the time period when there was no ceiling tile in the store. Additionally, the tile was reportedly replaced with the same type of ceiling tile from the same manufacturer. The existing ceiling tile could be removed and a more systematic evaluation conducted to determine if this resolve the odor problem. If this is the case, ceiling tile constructed of different material could be installed. Modifications to ensure the space above the false ceiling is maintained under negative pressure and controlling the potential for condensate or leaks onto the ceiling tile may also be necessary.

3. Dirt and debris under the merchandise flats in the sales area are a potential source of microbial growth. Janitorial practices should include routinely cleaning underneath the flats.

4. Housekeeping in the stock room needs to be improved. Aisles should be kept clear and excess stock properly stored. Smoking should not be permitted inside the facility.

5. Conduct a comprehensive inspection of the plumbing system (drain pipes, traps, and drain vents), including both the roof drain and sanitary sewer system supporting this location to ensure that there are no leaks or other problems. Although the odor did not appear to be consistent with a "bathroom" smell, this inspection should be conducted to rule out this possibility.

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Table 1 Temperature, Relative Humidity, and Carbon Dioxide Monitoring Results Prestonsburg, Kentucky HETA 98-0300-2723 September 23-24, 1998						
Location	Carbon Dioxide (PPM)		Relative Humidity (%)		Temperature °F	
	9/23: 2:30 PM	9/24: 10:00 AM	9/23: 2:30 PM	9/24: 10:00 AM	9/23: 2:30 PM	9/24: 10:00 AM
1. Store Entrance	600	575	36	49	76.5	66
2. Center of Store	600	550	37	48	74	66
3. Back center of Store	600	570	38	48	73	65
4. Bathroom Entrance	580	530	38	47	72	65
5. Back of Store - South	580	560	40	47	72	65
6. Stock room	550	550	42	46	71	65
7. Outside	420	450	40	61	73	62

PPM = parts of gas or vapor per million parts air

Table 2
Bulk Microbiological Sample Results
Dollar General Store, Prestonsburg, Kentucky
HETA 98-0300-2723

Sample Description	Fungal/Bacterial ID	Colony Counts	Concentration (CFU/g)	Percentage of Total
Sheetrock between stock room and sales floor. **BA-1.**	Fungi: No Growth	NA	<699	NA
	Dominant Species, Bacteria: *Bacillus megatarium* *Bacillus pumilus*	3	2098	100
Ceiling tile obtained at entrance to bathroom **BA-2**	Fungi: No Growth	NA	<719	NA
	Bacteria: No Growth	NA	<719	NA
Dust/Debris from display Flat in back center (3rd aisle) **BA-3**	Fungi: *Curvularia* *Epicoccum nigrum* *Phoma* *Rhodotorula* sterile fungi yeasts	74 33 2 109 46 14	54,412 24,265 1471 80,147 33,824 10,294 **Total: 204, 412**	27 12 <1 39 17 95
	Dominant Species, Bacteria *Oerskovia* sp. *Cellulomonas sp.* *Citrobacter freundii*	217	6,541,912	100
Dust/Debris from display Flat in front of store. **BA-4**	Fungi: *Cladosporium* *Epicoccum nigrum* *Fusarium* sterile fungi	1 3 1 3	532 1,596 532 1,596 **Total: 4,225**	13 38 13 38
	Dominant Species, Bacteria *Bacilus cereus* *Acinetobacter calcoaceticus* *bacillus sp.*	79	42,021	100
Floor tile and debris from base of support pole in center of store **BA-5**	Fungi: No Growth	NA	<481	NA
	Dominant Species, Bacteria *Bacillus Subtilis*	4	1,923	100
Floor tile and debris from south east side of sales floor	Fungi: *Cylindrocarpon* *Penicillium*	35 1	17,949 413 **Total: 18,462**	97 3
	Dominant Species, Bacteria *Oerskovia sp* *Brevibacterium caseie* *Comamonas acidovorans*	158	13,288,210	100

Notes : < = Less Than
cfu/g = colony forming units per gram sample

APPENDIX A - INDOOR ENVIRONMENTAL QUALITY

A number of published studies have reported a high prevalence of symptoms among occupants of office buildings.[1-5] NIOSH investigators have completed over 1200 investigations of the indoor environment in a wide variety of settings since 1971. However, the great majority of these investigations have been conducted since 1979.

The symptoms reported by building occupants have been diverse and usually not suggestive of any particular medical diagnosis or readily associated with a causative agent. A typical spectrum of symptoms has included headaches, unusual fatigue, varying degrees of itching or burning eyes, irritations of the skin, nasal congestion, dry or irritated throats, and other respiratory irritations. Typically, the workplace environment has been implicated because workers report that their symptoms lessen or resolve when they leave the building.

Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[6,7] Among these factors are imprecisely defined characteristics of HVAC systems, cumulative effects of exposure to low concentrations of multiple chemical pollutants, odors, elevated concentrations of particulate matter, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise.[4-8] Reports are not conclusive as to whether increases of outdoor air above currently recommended amounts are beneficial.[9] However, rates lower than these amounts appear to increase the rates of complaints and symptoms in some studies.[10] Design, maintenance, and operation of HVAC systems are critical to their proper functioning and provision of healthy and thermally comfortable indoor environments. Indoor environmental pollutants can arise from either indoor or outdoor sources.[11]

There are also reports describing results which show that occupant perceptions of the indoor environment are more closely related to the occurrence of symptoms than the measurement of any indoor contaminant or condition.[12] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[13,14]

Less often, an illness may be found to be specifically related to something in the building environment. Some examples of potentially building-related illnesses are allergic rhinitis, allergic asthma, hypersensitivity pneumonitis, Legionnaires' disease, Pontiac fever, carbon monoxide poisoning, and irritant reaction to boiler corrosion inhibitors. The first three conditions can be caused by various microorganisms or other organic material. Legionnaires' disease and Pontiac fever are caused by *Legionella* bacteria. Sources of carbon monoxide include vehicle exhaust and inadequately ventilated kerosene heaters or other fuel-burning appliances. Exposure to boiler additives can occur if boiler steam is used for humidification or is released by accident.

Problems that NIOSH investigators have found in the non-industrial indoor environment have included poor air quality due to ventilation system deficiencies, overcrowding, volatile organic chemicals from office furnishings, office machines, structural components of the building and contents, tobacco smoke, microbiological contamination, and OA pollutants; comfort problems due to improper temperature and RH conditions, poor lighting, and unacceptable noise levels; adverse ergonomic conditions; and job-related psychosocial stressors. In most cases, however, no environmental cause of the reported health effects could be determined.

Standards specifically for the non-industrial indoor environment do not exist. NIOSH, OSHA, and ACGIH have published regulatory standards or recommended limits for occupational exposures.[15,16,17] With few exceptions, pollutant concentrations observed in the office work environment fall well below these published occupational standards or recommended exposure limits. ASHRAE has published recommended building ventilation and thermal comfort guidelines (Figure 1).[18,19] The ACGIH has also developed a manual of guidelines for approaching investigations of building-related symptoms that might be caused by airborne living organisms or their effluents.[20]

Measurement of indoor environmental contaminants has rarely proved to be helpful, in the general case, in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proved relationship between a contaminant and a building-related illness. However, measuring ventilation and comfort indicators such as CO_2, temperature, and RH is useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems.

Carbon Dioxide (CO_2)

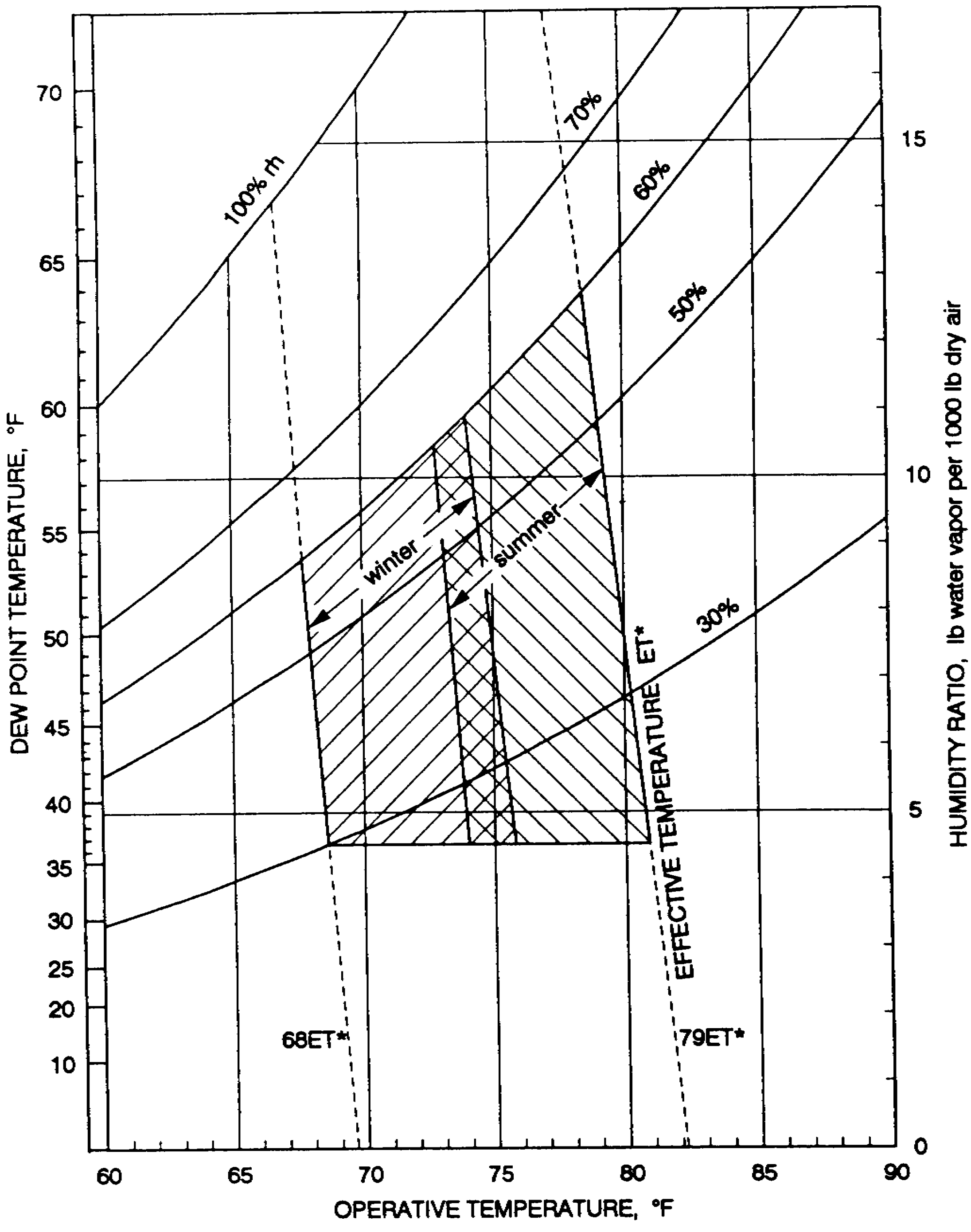
Carbon dioxide is a normal constituent of exhaled breath and, if monitored, can be used as a screening technique to evaluate whether adequate quantities of OA are being introduced into an occupied space. ASHRAE's most recently published ventilation standard, ASHRAE 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 20 cubic feet per minute per person (cfm/person) for office spaces, and 15 cfm/person for reception areas, classrooms, libraries, auditoriums, and corridors.[19] Maintaining the recommended ASHRAE outdoor air supply rates when the outdoor air is of good quality, and there are no significant indoor emission sources, should provide for acceptable indoor air quality.

Indoor CO_2 concentrations are normally higher than the generally constant ambient CO_2 concentration (range 300-350 ppm). Carbon dioxide concentration is used as an indicator of the adequacy of OA supplied to occupied areas. When indoor CO_2 concentrations exceed 800 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected.[21] Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased. It is important to note that CO_2 is not an effective indicator of ventilation adequacy if the ventilated area is not occupied at its usual level.

Temperature and Relative Humidity (RH)

Temperature and RH measurements are often collected as part of an indoor environmental quality investigation because these parameters affect the perception of comfort in an indoor environment. The perception of thermal comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperature.[22] Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. The American National Standards Institute (ANSI)/ASHRAE Standard 55-1981 specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally acceptable (Figure 1).[18] Assuming slow air movement and 50% RH, the operative temperatures recommended by ASHRAE range from 68-74° F in the winter, and from 73-79° F in the summer. The difference between the two is largely due to seasonal clothing selection. ASHRAE also recommends that RH be maintained between 30 and 60% RH.[18] Excessive humidity can support the growth of microorganisms, some of which may be pathogenic or allergenic.

Figure 1
ANSI/ASHRAE Standard 55-1992
Thermal Environmental Conditions
for Human Occupancy



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APPENDIX B - MICROBIAL CONTAMINATION

Microorganisms (including fungi and bacteria) are normal inhabitants of the environment. The saprophytic varieties (those utilizing non-living organic matter as a food source) inhabit soil, vegetation, water, or any reservoir that can provide an ample supply of a nutrient substrate. Under the appropriate conditions (optimum temperature, pH, and with sufficient moisture and available nutrients) saprophytic microorganism populations can be amplified. Through various mechanisms, these organisms can then be disseminated as individual cells or in association with soil/dust or water particles. In the outdoor environment, the levels of microbial aerosols will vary according to the geographic location, climatic conditions, and surrounding activity. In a "normal" indoor environment, the level of microorganisms may vary somewhat as a function of the cleanliness of the HVAC system and the numbers and activity level of the occupants. Generally, the indoor levels are expected to be below the outdoor levels (depending on HVAC system filter efficiency) with consistently similar ranking among the microbial species.[1,2]

Some individuals manifest increased immunologic responses to antigenic agents encountered in the environment. These responses and the subsequent expression of allergic disease is based, partly, on a genetic predisposition.[3] Allergic diseases typically associated with exposures in indoor environments include allergic rhinitis (nasal allergy), allergic asthma, allergic bronchopulmonary aspergillosis (ABPA), and extrinsic allergic alveolitis (hypersensitivity pneumonitis).[4] Allergic respiratory diseases resulting from exposures to microbial agents have been documented in agricultural, biotechnology, office, and home environments.[5,6,7,8,9,10,11,12]

Individual symptomatology varies with the disease. Allergic rhinitis is characterized by paroxysms of sneezing; itching of the nose, eyes, palate, or pharynx; nasal stuffiness with partial or total airflow obstruction; and rhinorrhea (runny nose) with postnasal drainage. Allergic asthma is characterized by episodic or prolonged wheezing and shortness of breath in response to bronchial (airways) narrowing. Allergic bronchopulmonary aspergillosis is characterized by cough, lassitude, low-grade fever, and wheezing.[13] Heavy exposures to airborne microorganisms can cause an acute form of extrinsic allergic alveolitis which is characterized by chills, fever, malaise, cough, and dyspnea (shortness of breath) appearing four to eight hours after exposure. In the chronic form, thought to be induced by continuous low-level exposure, onset occurs without chills, fever, or malaise and is characterized by progressive shortness of breath with weight loss.[14]

Acceptable levels of airborne microorganisms have not been established, primarily because allergic reactions can occur even with relatively low air concentrations of allergens, and individuals differ with respect to immunogenic susceptibilities. The current strategy for on-site evaluation of environmental microbial contamination involves an inspection to identify sources (reservoirs) of microbial growth and potential routes of dissemination. In those locations where contamination is visibly evident or suspected, bulk samples may be collected to identify the predominant species (fungi, bacteria, and thermoactinomycetes). In limited situations, air samples may be collected to document the presence of a suspected microbial contaminant. Air sample results can be evaluated epidemiologically by comparing those from the "complaint areas" to those from non-complaint areas, or by relating exposure to immunologic findings.

Microbial Decontamination in HVAC Systems - Recommendations

1. All sources of moisture in or near the AHU, including the leaks in the foundation, standing water in the condensate drain pans of the cooling coils, and standing water in the sumps located in the ventilation system, should be identified and repaired.

2. Contaminated or moisture-damaged fiberglass sound liners should be discarded and replaced, preferably with a smooth-surfaced insulation to prevent the collection of microbial contaminants. Subsequent to the removal of the insulation, all surfaces (nonporous and porous) should be dried and cleaned with a high-efficiency particulate air (HEPA)-filtered vacuum to remove dirt, debris, and microorganisms before removal. The surface of the insulation should not be damaged by vacuuming. All remedial activities should be performed when the building is vacant and when the HVAC system is decommissioned. All materials should be discarded appropriately according to state and local regulations.

   During renovation, the spread of contaminants (e.g., bioaerosols, debris, and fiberglass fibers) through recirculation of air to occupied spaces needs to be controlled. This may be accomplished by: (1) isolating areas being renovated from the rest of the building (including negative pressurization to prevent exfiltration of contaminated air), (2) exhausting air contaminants from the area undergoing renovation directly to the outdoors, and (3) sealing off ductwork to prevent the redistribution of contaminated air and contamination of ductwork.

3. During the removal of any damaged materials, precautions should be taken to minimize exposures to the remediation workers performing the abatement. Remediation efforts should include provisions for the proper protection of the individuals conducting the remediation work. Workers should wear respiratory protection consisting of high efficiency particulate air (HEPA) filters and adequate skin and eye protection.

4. A formal written preventative maintenance schedule for the AHU should be implemented in consultation with the manufacturers of the equipment. Preventative maintenance on the equipment should be documented and the documentation kept in a file to assure continuity between mechanical personnel. The HVAC cooling coils and condensate drip pans should be kept free of standing water and visible microbial growth. Throughout the year, coils, condensate pans, and drains should be inspected monthly and, if necessary, cleaned. Pill packs should not be used to keep the drip pans free of debris or biological growth. These tablets are not effective unless a sufficient pool of water in the pan enables the tablet to dissolve evenly throughout the pan. The floor of the fan room should be kept free of debris which could become entrained into the SA stream.

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