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OAKLAND SPORTS THERAPY AND WORK HARDENING
EXTON, PENNSYLVANIA

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Summary

On September 15, 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request from employee's to conduct a health hazard evaluation (HHE) at Oakland Sports Therapy and Work Hardening. The evaluation was requested as a result of recurring headaches, dizziness, eye irritation, sinus infections, and respiratory problems reported by the staff.

An indoor environmental evaluation was conducted on January 26-27, 1993. Environmental measurements for temperature, relative humidity (RH), carbon dioxide (CO_2), and bromine were collected. The design and performance of the air-handling units were also evaluated. Questionnaires were distributed to the employees to obtain information regarding employees' symptoms and perception of the building environment.

The temperature and RH measurements were slightly below comfort guidelines recommended by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). Indoor temperatures ranged from 62-74°F, whereas the RH ranged from 21-33%. Carbon dioxide (CO_2) concentrations throughout the facility were consistently in excess of 1,000 parts per million (ppm). The CO_2 levels and ventilation assessment indicated that the center may not receive an adequate amount of OA during maximum occupancy. Trace levels of bromine were detected in two of the three samples collected. These concentrations would not be expected to cause health effects.

Thirteen of 14 questionnaires (response rate of 94%) were returned and analyzed. The most commonly reported symptoms were dry, itching, or irritated eyes, headaches, dizziness or lightheadedness, unusual tiredness, fatigue, or drowsiness, and stuffy or runny nose or sinus congestion. In general, many employees had complaints regarding environmental comfort, such as temperature and humidity, ventilation airflow, and presence of chemical odors.

Employee questionnaires revealed that many of the employees have experienced symptoms consistent with those commonly referred to as "building-related" symptoms. The environmental data gathered during this investigation indicate that the amount of OA supplied to the occupied areas was below the ventilation guidelines recommended by ASHRAE. Increasing the amount of OA should not only reduce the CO_2 levels but also further reduce the bromine levels. Other recommendations include relocating the OA intake, balancing the ventilation system, and using more efficient filter media.

Keywords: SIC 8049 (Offices and Clinics of Health Practitioners, not otherwise classified), indoor environmental quality, IEQ, IAQ, carbon dioxide, temperature, relative humidity, ventilation, bromine, whirlpool.

Introduction

On September 15, 1992, the National Institute for Occupational Safety and Health (NIOSH) received an employee request to conduct a health hazard evaluation at Oakland Sports Therapy and Work Hardening, located in Exton, Pennsylvania. The request for an indoor environmental quality (IEQ) investigation was submitted as a result of various health complaints, such as headaches, dizziness, eye irritation, sinus infections, and respiratory problems, being attributed to the work environment in this building.

An initial site visit was conducted on January 26-27, 1993, during which environmental samples were collected, the air-handling units (AHUs) were evaluated, and medical questionnaires were administered. The preliminary findings and recommendations were discussed with the management and employee representatives at the closing conference on January 27, 1993.

Background

Oakland Sports Therapy and Work Hardening is located within the first floor of a two-story brick structure. The facility, built in 1990, is part of a medical complex in a suburban area. As shown in Figure 1, the center is 36,000 square feet with a majority of the facility dedicated to an open area for physical therapy rehabilitation services. In this open area, there are treadmills, stationary bikes, Nautilus® equipment, whirlpools and an Aqua Ark® for water therapy, and other physical therapy equipment, along with the staff and secretarial areas. The center also has three treatment rooms and two managerial offices. There are 14 employees at the facility and typically, 6-7 clients performing rehabilitative therapy. Smoking is prohibited throughout the building.

Ventilation

Description

Two of the 17 heat pumps, located on the roof, condition the air for the center. One unit services the east side and the other is dedicated to the west side of the center; each heat pump is controlled by a single thermostat equipped with a sensor. During the winter months, the manually-controlled thermostats are lowered to 50-60°F during unoccupied hours to conserve energy.

Each heat pump removes air from the open area, mixes the return air with outside air (OA), filters and conditions (heats or cools) the air, and then supplies the mixed air back to the facility. A constant volume of air is supplied to the center through louvered diffusers located in the ceiling. The offices and treatment rooms which do not have direct exhausts are designed to be under positive pressure (the air flows out of the rooms into the hallways). Air entering the hallways then flows to the ceiling-mounted return registers in the middle of the open area in the facility. Air is delivered to the heat pumps through a ducted return system. The exhaust system fan is located on the roof.

Outside Air Provisions

Outside air is delivered directly to the center from the main supply duct. According to the contractor who installed the ductwork, the system is designed to supply 10% OA to the facility. An alternate unintended supply path is leakage through open doors.

Filters

The heat pumps use fiberglass panel filters similar to those used in home furnaces. The filters have an American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) dust spot test efficiency of less than 20%.

Preventative Maintenance

A service contractor maintains the AHUs. The filters are discarded and replaced with new filters once a week. Every three months the entire system is inspected and the necessary repairs are made.

Aqua Ark

Aqua Ark® is a large (8 feet by 6 feet by 8 feet) whirlpool used in conjunction with physical therapy exercises. When the whirlpool is not in use, it is covered with a thick, plastic tarp to prevent heat loss and evaporation.

Bromine, used as the sanitizer, is maintained at a concentration of 3 parts per million (ppm) or milligrams of substance per liter of water. The pH of the water is maintained at a level of 7.5, with adjustments made using sodium bicarbonate.

The chemicals in the water are routinely monitored throughout the day. Once every two weeks, bromine tablets are added to the brominator, an automatic metering system for bromine. One individual is responsible for this task, along with maintaining records of testing and treatment.

Evaluation Criteria

Indoor Environmental Quality

NIOSH investigators have completed over 1,100 investigations of the occupational indoor environment in a wide variety of non-industrial settings. The 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 degree 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.

A number of published studies have reported a high prevalence of symptoms among occupants of office buildings.[1,2,3,4,5] 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 heating, ventilating, and air-conditioning (HVAC) systems, cumulative effects of low concentrations of multiple chemical pollutants, odors, elevated concentrations of particulate matter, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise.[8,9,10,11,12,13,14] Reports are not conclusive as to whether increases of OA above currently recommended amounts (greater than 15 cubic feet per minute per person) are beneficial.[11] However, rates lower than these amounts appear to increase the rates of complaints and symptoms in some studies.[15] Design, maintenance, and operation of HVAC systems are critical to their proper functioning and provision of health and thermally comfortable indoor environments. Indoor environmental pollutants can arise from either outdoor sources or indoor sources.[16]

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.[17,18,19] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[17,20,21,22]

Less often, an illness may be found to be specifically related to something in the building environment. Some examples of potential building-related illnesses are allergic rhinitis, allergic asthma, hypersensitivity pneumonitis, Legionaries' disease, Pontiac fever, carbon monoxide poisoning, and reaction to boiler corrosion inhibitors. The first three conditions can be caused by various microorganisms or other organic material. Legionaries' disease and Pontiac fever are caused by *Legionella* bacteria. Sources of carbon monoxide include vehicle exhaust and inadequate 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 furnishing, machines, structural components of the building and contents, tobacco smoke, microbiological contamination, and OA pollutants; comfort problems due to improper temperature and relative humidity conditions, poor lighting, and unacceptable noise levels; adverse ergonomic conditions; and job-related psychosocial stressors. In most cases, however, no cause of the reported health effects could be determined.

Standards specifically for non-industrial indoor environment do not exist. NIOSH, the Occupational Safety and Health Administration (OSHA), and the American Conference of Governmental Industrial Hygienists' (ACGIH) have published regulatory standards or recommended limits for occupational exposures.[23,24,25] 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 design criteria and thermal comfort guidelines.[26,27] 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.[28]

Measurement of indoor environmental contaminants has rarely proved 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 contaminant and a building-related illness. The low-level concentrations of particles and variable mixtures of organic materials usually found are difficult to interpret and usually impossible to casually link to observed and reported health symptoms. However, measuring ventilation and comfort indicators such as CO_2, temperature, and RH are useful in the early stages of an investigation in providing information relative to the proper functioning and control of the HVAC systems.

NIOSH and the Environmental Protection Agency (EPA) jointly published a manual on building air quality, written to help prevent environmental problems in buildings and solve problems when they occur.[29] This manual suggests that indoor environmental quality (IEQ) is a constantly changing interaction of a complex set of factors. Four of the most important elements involved in the development of IEQ problems are: 1) a source of odors or contaminants; 2) a problem with the design or operation of the HVAC system; 3) a pathway between the contaminant source and the location of the complaint; 4) and the building occupants. A basic understanding of these factors is critical to preventing, investigating, and resolving IEQ problems.

Carbon Dioxide

CO_2 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. ANSI/ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends OA supply rates of 20 cfm/person for office spaces, and 15 cfm/person for corridors, and physical therapy treatment and reception areas.[19] Maintaining the recommended ASHRAE outdoor air supply rates when the outdoor air is of good quality, and if 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). When indoor CO_2 concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. CO_2 is not thought to be a cause of indoor environmental quality symptoms. Rather, it used as an indicator of the adequacy of OA supplied to the occupied areas. 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 if the ventilated area is vacated or sparsely populated.

Temperature and Humidity

Temperature and RH parameters affect the perception of comfort in the indoor environment. The perception of thermal comfort is related to one's metabolic heat production, transfer of heat to the environment, physiological adjustments, and body temperatures. Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. ANSI/ASHRAE Standard 55-1981 specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally acceptable. Assuming slow air movement and 50% RH, the operative temperatures recommended by ASHRAE range from 68-74°F in the winter, and 73-79°F in the summer.[18] The difference between the two is largely due to seasonal clothing selection. In a separate document (ASHRAE Standard 62-1989), ASHRAE recommends that the RH be maintained between 30 and 60%.[19] Excessive humidities can support the growth of microorganisms, some of which may be pathogenic or allergenic.

Bromine

Bromine can cause acute irritation of the eyes, respiratory tract, skin, and mucous membranes. Inhalation and skin absorption are the major routes of exposure. The main effects associated with low exposure to bromine are cough, nose bleeds, respiratory difficulty, dizziness, headaches, and vertigo. These symptoms can be followed by nausea, abdominal pain, diarrhea, and sometimes, a measle-like eruption on the face, trunk, and extremities.[30]

Studies have shown that exposures at less than 1 ppm of bromine will cause lacrimation, the formation of tears in the eyes. At 10 ppm, exposures are intolerable, causing severe irritation of the upper respiratory tract.[31] The NIOSH Recommended Exposure Limit (REL), OSHA Permissible Exposure Limit (PEL), and ACGIH Threshold Limit Values (TLV) for bromine are

0.1 ppm for an 8-hour time-weighted average (TWA). NIOSH and ACGIH have also set a recommended short-term exposure limit (STEL) of 0.3 ppm for a 15-minute sampling period.[23,24,25]

Evaluation Methods

Ventilation

On January 26-27, 1993, an inspection was made of all accessible components of the air handling units. Smoke tests were conducted to subjectively evaluate the relative pressure of the treatment rooms and offices with respect to the hallways leading to the open area. For each of the rooms, the direction of smoke was observed at the gap between the floor and the bottom of the door, with the door closed.

Direct measurements of the amount of OA was not possible due to the configuration of the system; however, the volume rate of airflow was measured at the supply air and exhaust diffusers using the Shortridge Airdata™ Multimeter/Flowhood ADM Model 860/8405 with an Electronic Micromanometer equipped with a 2 feet by 2 feet skirt. Measurements with the flowhood were made with the flaps closed and with the use of a flow distribution grille. In addition, the measurements were compensated for supply air temperature and local barometer. Therefore, the measurements were made in actual rather than standard flow. The amount of airflow measured were then compared to the design specifications provided by the contractor (engineering prints were not available).

Carbon Dioxide

On January 27, 1993, CO_2 measurements were collected at 14 locations throughout the facility and outside. Each location was evaluated six times between 7:00 a.m. and 6:30 p.m. to determine changes in these parameters.

Real-time CO_2 levels were measured using Gastech Model RI-411A, Portable CO_2 indicator. This portable, battery operated instrument monitors CO_2 via nondispersive infrared absorption with a range of 0-4975 ppm, and a sensitivity of 25 ppm. Instrument zeroing was performed prior to use, as well as calibration with a known concentration of CO_2 span gas (800 ppm). Confirmation of calibration were conducted throughout the instrument use period.

Temperature and Humidity

Real-time temperature and RH measurements were also collected at 14 locations throughout the day using the TSI battery-operated, 8360 Velocicalc® Plus Air Velocity meter. This meter is capable of providing direct reading for dry bulb temperature and RH ranging from -4 to 140°F, and 0 to 95%, respectively.

Bromine

Three general area air samples were collected for bromine at the Aqua Ark® and outside of the center. Area air samples were collected on 25 millimeter (mm), 0.45 micron (µm) pore size, silver membrane filters in closed-face cassettes according to the NIOSH Method 6011.[32] The cassettes were connected via Tygon® tubing to Gillian Lo Flow Sampler® battery-operated personal sampling pumps. Sample air was drawn through the filters at a flow rate of 0.7 liters per minute (ℓ/min). After sampling, the filters were removed from the cassette, desorbed in sodium thiosulfate solution, and analyzed for bromine using ion chromgraphy, conductivity detection. The analytical limit of detection is 2.9 micrograms (µg) of bromine per sample, which equates to a minimum detectable concentration of 0.004 micrograms per cubic meter (µg/m^3) or 0.001 ppm, assuming a sample volume of 350 liters.

The sampling pumps were calibrated on-site prior to and after sampling using the Kutz Pocket Flow Calibrator™ mass flowmeter, which was calibrated against a primary standard. For subsequent calculation of sample volumes, the mean pre- and post sampling flow rates were used. Two field blanks were prepared and submitted with the sample set.

Medical Questionnaires

To obtain information regarding indoor environment issues, a self-administered questionnaire was distributed to all members of the staff and management in the center. The questionnaires asked if the employee experienced any of 13 symptoms commonly reported by occupants of "problem buildings" while at work on the day of the survey. Also, the questionnaire examines the frequency of occurrence of these symptoms during the past four weeks and whether the symptoms subside, stay the same, or worsen away from work. In a separate section in the questionnaire, information regarding employees perception of environmental parameters such as temperature, humidity, etc. during the past four weeks are obtained.

Discussion and Results

Ventilation

Airflow measurements are shown in Figure 1. Supply airflow rates ranged from 108 to 292 cfm. The total airflow from the supply diffusers was approximately 3,400 cfm. The exhaust airflow measurements ranged from approximately 195 to 770 cfm, with a total exhaust of 3,200 cfm. The measurements revealed that the amount of airflow decreases downstream from the main duct, indicating that the system is not balanced properly.

After health complaints had been reported, the contractor had added a supplemental supply above the Aqua Ark® to dilute any contaminants from the whirlpool. Airflow measurements indicate that this supply was not functioning properly, and it was actually exhausting approximately 46 cfm of air instead of supplying air.

According to the contractor who installed the ductwork, the ventilation system is designed to supply 10% outside air. Based on the total airflow measurements of 3,400 cfm, there should be approximately 340 cfm of OA supplied to the entire center. According to the ASHRAE guidelines for a physical therapy and treatment center, a maximum of 22 people could be accommodated at the center, assuming proper distribution of OA to the occupied spaces. According to the staff, there are on an average, 20 people occupying the center at a given time. However, there are times in which the center may not meet the ventilation guideline requirements.

The OA intake was located on the roof within 25 feet of the sanitary exhaust outlet. Due to the close proximity of the inlet and outlet, there is the possibility that exhausted contaminant air could re-enter the building through the OA intake.

The visual assessment of the air pressure differentials indicate that the offices and treatment rooms are under positive pressure with respect to the hallways.

Carbon Dioxide

A location composite of the average CO_2 levels was tabulated and is shown in Figure 2. The CO_2 concentrations ranged from 475 to 525 ppm at the beginning of the work day. After the building was occupied, the CO_2 levels rose to 725 to 900 ppm and remained relatively constant until the afternoon. By the late afternoon, the CO_2 concentrations increased and consistently exceeded

1,000 ppm throughout the rest of the day. The elevated CO_2 concentrations suggest that the OA delivered to this facility is inadequate for the level of occupancy.

Temperature and Relative Humidity Levels

Indoor temperature ranged from 62-74°F, whereas the RH ranged from 21 to 33%. The measurements were slightly below the temperature and RH guidelines recommended by ASHRAE; however, by the second reading collected at approximately 10 am, the temperatures were within acceptable ranges. The RH levels were below the ASHRAE comfort guidelines for winter conditions. The colder and drier weather conditions (37°F and 37% RH) as well as the heating of the building, contribute to the lower RH levels. Although low RH may produce discomfort due to dryness, it does help restrict microbiological growth. The concerns over discomfort should be balanced against the risk of increased microbiological growth associated with humidification.

Bromine

A total of three air samples were collected for bromine due to the concern regarding irritation attributed to the Aqua Ark®. The concentrations detected inside the facility ranged from none detected to 0.001 ppm, compared to 0.0003 ppm observed outside the facility. These levels are all below the limit of quantification. Hence, the precision of the sample results may be reduced.

Standards for indoor environmental quality in this setting do not exist. However, the regulatory standards and recommended limit for occupational exposures in industrial environments of 0.1 ppm for bromine are orders of magnitude higher than the concentrations found in the Oakland facility. Although one sample is higher in the center than the outside control, it is unclear what health or comfort effects may result at this low concentration.

Medical

On January 28, 1993, a self-administered questionnaire was distributed and collected from 14 employees; however, only 13 employees chose to participate in the study (response rate = 94%). Table 1 shows the percentage of workers who experienced symptoms on the day of the survey. The most commonly reported symptoms were dry, itching, or irritated eyes, headaches, dizziness or lightheadedness, unusual tiredness, fatigue, or drowsiness, and stuffy or runny nose or sinus congestion.

Also included in this table is the percentage of employees who reported experiencing the respective symptom once a week or more while at work in the past four weeks preceding this survey. In general, the results were similar to the responses shown on the day of the survey.

Table 1 shows the percentage of workers experiencing the respective symptom once a week or more often while at work in the preceding four weeks, and also reported that the symptom tended to get better away from work. This latter criterion has, in some studies, been used to define a "building-related symptom," but it is possible that a symptom, which does not improve when away from the building, may also be due to conditions at work. The addition of the criterion regarding symptom improvement when away from work decreased the percentage of positive responses for individual symptoms, except for headaches and unusual tiredness, fatigue, or drowsiness in which the percentage of complaints remained constant. Many of the employees still reported experiencing one or more "building-related symptoms."

Table 2 shows the responses to the questions regarding environmental comfort in the facility. In general, many employees had complaints about temperature and humidity, ventilation airflow, and presence of chemical odors.

Conclusions and Recommendations

Over the past year, there has been concern regarding the symptoms being experienced by the staff at Oakland Sports Therapy and Work Hardening. The questionnaire survey revealed that many workers had frequently experienced symptoms while in the facility and in many cases, the symptoms improved when they were away from work.

Reports of building-related symptoms have been increasingly more common in recent years. Unfortunately, the causes of these health complaints have not been clearly identified. Many factors are suspected (volatile organic compounds, inadequate amounts of OA, etc.). Although it is difficult to identify concentrations of specific contaminants that are associated with the symptoms reported, many researchers feel that the occurrence of occupants symptoms can be lessened by providing a properly maintained building environment. The NIOSH investigation identified a number of deficiencies at the Oakland facility.

1. CO_2 concentrations throughout the facility increased quickly in the afternoon, up to 1,250 ppm in some areas. Indoor CO_2 levels in excess of 1,000 ppm is suggestive that the center is not receiving adequate amounts of OA. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased. Therefore, the amount of OA supplied should be increased. A firm specializing in mechanical engineering should be consulted to determine the amount of OA currently being provided to the center as well as assessing the capabilities and

limitations of the existing systems to provide additional OA. The amount of OA should be increased to meet the recommendations set forth by ASHRAE 62-1989 during maximum occupancy.

2. Bromine concentrations were detected at the center in extremely low concentrations. It is unclear what health or comfort effects may result form exposures to bromine at such low concentrations. However, ventilation changes to increase the amount of fresh air should further reduce the bromine levels.

3. Airflow measurements indicate that the ventilation system is not balanced since there is an uneven distribution of air throughout the facility. The systems should be re-tested and balanced by an engineering firm which is certified by the National Environmental Balancing Bureau.

4. The contractor installed a supplemental supply above the Aqua Ark® to aid in the dilution of any contaminants from the whirlpool. Airflow measurements indicate that this supply was not functioning properly. The source of the problem should be determined and repaired. If the situation can not be remedied, a local exhaust ventilation system should be installed. Ideally, the Aqua Ark® should be placed in a separate room which is under negative pressure and has its own dedicated exhaust. Ventilation measurements should be performed to evaluate the installation and/or modifications of the system to determine whether it is functioning according to design.

5. Filters with an ASHRAE dust spot efficiency rating of 35 to 60% should be used, as recommended by ASHRAE, instead of the filters which are less than 20% efficient currently being used. A mechanical firm should be consulted to determine the maximum filter efficiency that can be used.

6. The OA intake is within 25 feet of an exhaust outlet. Due to the close proximity of the intake and exhaust vent, there is the potential for re-entrainment of contaminated air. The OA inlet should be relocated so that the exhausted air is less likely to enter the intake. Alternative solutions would be to relocate the contaminant source (exhaust vent) away from the OA intake or increase the height of exhaust vent on the roof to reduce the chance of recirculation into the nearby intake.

7. Central files should be developed for the heat pump units. These files should include specifications, design drawings, product literature, operation parameters, and other important information to assure continuity between mechanical personnel.

8. The temperature levels measured in the early morning were below the comfort guidelines recommended by ASHRAE. During the winter months, the thermostats are lowered to conserve on heat prior to leaving the facility. The thermostats should either be placed on a automatic system which would adjust the temperature to a level within the comfort guidelines before the beginning of the shift or the thermostats should not be decreased below the comfort guidelines of 68°F.

Authorship and Acknowledgements

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Copies of this report have been sent to:

1. Oakland Sports Therapy and Work Hardening

2. OSHA Region III

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.

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