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METRO TRANSIT
KALAMAZOO, MICHIGAN

NIOSH INVESTIGATOR:
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I. SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) received a request from the Amalgamated Transit Union Local #1093 to conduct a Health Hazard Evaluation (HHE) at the Metro Transit bus terminal located in Kalamazoo, Michigan. Several employees had complained of respiratory irritation when occupying the bus storage area of the facility.

On November 30 and December 1, 1993, environmental monitoring was conducted in the bus storage and garage areas of the facility. Environmental monitoring included full-shift time-weighed average (TWA) and 15-minute short-term sampling for exposures to diesel exhaust components such as carbon monoxide (CO), nitrogen dioxide (NO_2), and hydrocarbons. Workers potentially exposed to these substances were bus drivers, service lane attendants, and mechanics.

Air sampling results revealed personal breathing-zone exposures to CO as high as 5.8 parts per million (ppm), below the most stringent exposure criteria of 25 ppm adopted by the American Conference of Governmental Industrial Hygienists (ACGIH) for an 8-hour TWA exposure. For 15-minute short-term exposures, CO levels peaked at 2.1 ppm, well below the NIOSH ceiling limit of 200 ppm. The highest TWA concentration for NO_2 was 1.2 ppm, below the ACGIH TLV of 3 ppm. Short-term exposure measurements for NO_2 revealed concentrations that peaked at 4.6 ppm, exceeding the NIOSH short-term exposure limit (STEL) of 1 ppm for a 15-minute period, and approaching the Occupational Safety and Health Administration (OSHA) STEL of 5 ppm. The most predominant individual hydrocarbons measured at each sampling location were toluene and xylene. Toluene, xylene, and total petroleum hydrocarbons were present at low levels (the highest levels were less than 1% of the most stringent exposure criteria). An area air sample collected in the transmission repair room revealed hydrocarbon concentrations that were only 8% of the most stringent exposure criteria.

Based on the environmental data obtained during this investigation, the investigator concluded that elevated exposures to NO_2 is an indication that diesel exhaust emissions are associated with respiratory irritation reported by Metro Transit workers. Recommendations are made in section VII of this report to implement feasible means of reducing diesel exhaust emissions and worker exposures.

Keywords: SIC 4172 (Maintenance and Service Facilities for Motor Vehicle Passenger Transportation), diesel exhaust, hydrocarbons, carbon monoxide, nitrogen dioxide.

II. INTRODUCTION

On February 8, 1993, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Amalgamated Transit Union Local 1093 to conduct a Health Hazard Evaluation (HHE) at the Metro Transit bus terminal located in Kalamazoo, Michigan. The request stated that employees had experienced respiratory irritation believed to be associated with diesel-engine exhaust emissions that are generated in the bus storage area of the facility. Employee representatives reported that symptoms experienced by workers were more prevalent during the morning start-up period.

In response to the HHE request, a NIOSH investigator conducted an industrial hygiene evaluation at the bus terminal on November 30 and December 1, 1993. Following an initial meeting with the management of Metro Transit and a union representative, to discuss the nature of the HHE request, environmental monitoring was conducted for several components of diesel exhaust emissions including carbon monoxide (CO), nitrogen dioxide (NO_2), and petroleum hydrocarbons.

III. BACKGROUND

The Metro Transit bus terminal is a 61,000 square foot facility that houses a fleet of 40 diesel-powered buses. Seventy-four employees include approximately 9 administrative personnel, 50 bus drivers, 11 mechanics, 2 service lane workers, and 3 utility personnel. Work areas include a bus storage area, a maintenance area, and administrative offices. Work areas of specific concern for this evaluation included the bus storage area and the transmission repair room located in the maintenance area.

Each morning the engines of buses are started and allowed to idle for several minutes in the storage area. For several hours during the morning (5:00 a.m. to 9:00 a.m.), a visible haze of diesel exhaust emissions becomes apparent due to incomplete combustion, particularly when diesel engines of the buses have cooled overnight. Drivers spend about 15 minutes each morning in the bus storage area to prepare buses for service. During the evening shift, two service lane attendants perform duties on buses such as refueling, checking fluids, and washing the interior and exterior of buses.

In the maintenance area, mechanics perform general automotive repairs on buses. An area of particular interest was the transmission repair room located in the maintenance area that has a Safety Kleen® degreaser tank containing a petroleum hydrocarbon solvent used to manually clean transmission parts. The transmission repair room is reportedly utilized about 4 to 5 days each month when there is a need for transmission repairs. When repairing transmissions, mechanics generally work in the room for 4 to 8 hours per day. Exhaust ventilation was provided by a wall unit axial exhaust fan (14 inches in diameter) located approximately 10 feet from the Safety Kleen® degreaser tank.

The ventilation of the bus storage area was provided by four air handling units (AHU) and eight exhaust fans, all of which were in operating condition during the NIOSH evaluation. Each AHU provides a supply air capacity of 10,000 cubic feet per minute (cfm) for a total supply air capacity of 40,000 cfm with no ducted return. When the overhead doors of the storage room are closed, the outside air damper for each AHU allows a 15% fixed rate of outside air to the area. When overhead doors open to allow buses to enter the storage area, the outside air dampers open to provide 100% outside air for about 6 minutes, controlled by an automatic timer. After 6 minutes, the dampers return to the provision of 15% outside air. The purpose of this is to provide additional ventilation to dilute exhaust emissions generated by buses that enter the area. During the morning start-up period it is standard operating procedure to open three garage doors, during which time the AHUs provided 100% outside air to the area. Each exhaust fan delivers 5,000 cfm, for a total exhaust capacity of 40,000 cfm. Heating was provided by 19 ceiling mounted unit heaters using hot water supplied by a steam boiler. There was no air-conditioning in the bus storage area.

IV. ENVIRONMENTAL EVALUATION AND METHODS

On November 30, 1993, following a walk-through survey of the bus storage area, personal breathing-zone (PBZ) measurements were made during the second shift on two service lane workers to assess their exposures to diesel-exhaust emissions and diesel fuel during refueling. The sampling periods for the two measurements were 257 minutes and 258 minutes. An area air sample was also collected in the service lane area for a sampling period of 229 minutes.

On December 1, 1993, air sampling was conducted in the garage area to evaluate drivers' exposures to diesel exhaust components during the morning start-up period when the greatest number of drivers entered the area. Fifteen-minute short-term exposure measurements for CO (n=2), NO_2 (n=2), and total hydrocarbons (n=2) were collected on bus drivers who entered the garage area to perform start-up procedures. Full-shift PBZ air samples for these substances were collected on two drivers for sampling periods that ranged from 289 minutes to 501 minutes. Full-shift air samplers remained on workers while they also performed their routine driving duties. One full-shift PBZ sample was collected in the maintenance area to evaluate potential hydrocarbon exposure among mechanics. Sampling periods for full-shift air samples ranged from 289 minutes to 501 minutes. An area air sample was collected in the bus storage area for a sampling period of 77 minutes.

The transmission room was not utilized on the day of the evaluation. To determine hydrocarbon levels generated in the room, two area air sample were collected side-by-side for 426 minutes and 438 minutes at breathing-zone height near the degreaser tank while in operation.

Air samples for hydrocarbons were collected on 150 milligrams (mg) charcoal sorbent tubes, using battery powered air sampling pumps calibrated at a flowrate of 200 cubic centimeters (cc) per minute, in accordance to NIOSH method 1500.[1] Area air samples were submitted and analyzed for qualitative screening. PBZ samples were analyzed quantitatively, based on the area air sample screening results. For the area air samples collected in the transmission repair room, one sample was analyzed qualitatively, and the remaining sample was analyzed quantitatively based on the qualitative results. Air sampling pumps were post calibrated immediately following each sampling period.

PBZ measurements for NO_2 and CO were made using Dräger® colorimetric passive detector tubes. Dräger® tubes used for NO_2 and CO both have a limit of detection (LOD) of 0.05 ppm and an accuracy of ±10 to 15%.

V. EVALUATION CRITERIA

A. General

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 ten 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] 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 RELs, 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 the report, industry is legally required to meet those levels specified by the OSHA standard. The applicable NIOSH, OSHA, and ACGIH exposure criteria are presented in Table I.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a chemical substance during a normal 8- to 10-hour workday. A short-term exposure limit (STEL) is defined as a 15-minute TWA which should not be exceeded at any time during the workday even if the 8-hour TWA is within the applicable exposure criteria. Ceiling limit is defined as the concentration of a substance that should not be exceeded at any time during the workday even if the 8-hour TWA is within applicable exposure criteria

B. Diesel Exhaust

Based on findings of carcinogenic responses in exposed rats and mice, NIOSH recommends that whole diesel exhaust be considered a potential occupational carcinogen and that exposures be reduced to the lowest feasible concentration.[4] In addition to the carcinogenic effects, eye irritation and reversible pulmonary function changes have been experienced by workers exposed to diesel exhaust.[4-7]

Diesel exhaust is a complex mixture that consists of both a gaseous and particulate fraction. The composition will vary greatly with fuel and engine type, maintenance, tuning, and exhaust gas treatment.[4,8] The gaseous constituents include carbon dioxide, carbon monoxide, nitrogen dioxide, oxides of sulfur and hydrocarbons. The particulate fraction (soot) of diesel exhaust is comprised of solid carbon cores produced during the combustion process. More than 95% of these particles are less than 1 micron diameter (µmd) size. It has been estimated that up to 18,000 different substances from the combustion process can be adsorbed onto diesel exhaust particulate.[4] Up to 65% of the total particulate mass may be these adsorbed substances and includes compounds such as polynuclear aromatic hydrocarbons (PAHs), some of which are carcinogenic.[4] Particles in this size range are considered respirable because when inhaled they reach the deeper, non-ciliated portions of the lungs where they may be retained. In general, particles greater than 7-10 µmd are all removed in the nasal passages and have little probability of penetrating to the lung. Particles smaller than this can reach the air-exchange regions (alveoli, respiratory bronchiole) of the lung, and are considered more hazardous.

As noted, based on the results of laboratory animal and human epidemiology studies, NIOSH considers whole diesel exhaust to be a potential occupational carcinogen.[4] The studies of rats and mice exposed to diesel emissions, especially the particulate portion, confirmed an association with lung tumors.[4] Human epidemiology studies also suggest an association between occupational exposure to whole diesel exhaust and lung cancer.[4,9]

In addition to the carcinogenic potential, many other components of diesel exhaust have known toxic effects. These effects include pulmonary irritation from nitrogen oxides, eye and mucous membrane irritation from sulfur dioxide and aldehyde compounds, and chemical asphyxiation effects from CO. Exposure criteria has been established for some of these compounds; however, there are no exposure limits directly applicable to evaluation of whole diesel exhaust emissions.

Assessing worker exposure to diesel exhaust is difficult because of the complex makeup of emissions, uncertainty about which specific agent(s) may be responsible for the carcinogenic properties, and the effect of other potential sources of similar compounds (e.g., tobacco smoke particles are also primarily <1 μmd). Measurements of some commonly found components of diesel exhaust have generally shown concentrations to be well below established exposure criteria. Although exposure criteria has not been established specifically for diesel exhaust, for the purpose of this HHE, air sampling was conducted for CO, NO_2, and hydrocarbons to determine exhaust and diesel component emission levels in the bus storage area. A summary of health effects and evaluation criteria of specific diesel exhaust components measured for the purpose of this evaluation are listed below.

1. <u>Carbon Monoxide (CO)</u>

   Carbon monoxide (CO) is a colorless, odorless, tasteless gas which can be a product of the incomplete combustion of organic compounds. CO combines with hemoglobin and interferes with the oxygen carrying capacity of blood. Symptoms include headache, drowsiness, dizziness, nausea, vomiting, collapse, myocardial ischemia, and death.[10] The NIOSH REL for CO is 35 ppm TWA for up to a 10-hour period, and a ceiling level (not to be exceeded at any time during the workday) of 200 ppm. The OSHA PEL for CO is 50 ppm based on an 8-TWA. The ACGIH TLV for CO is 25 ppm as an 8-hour TWA.

2. <u>Nitrogen Dioxide (NO_2)</u>

   Nitrogen dioxide (NO_2) is classified as a respiratory irritant that may cause pulmonary edema. Acute exposures has been associated to a productive cough, frothy sputum, and difficult breathing. There are no studies that suggest NO_2 poses carcinogenic, mutagenic, and teratogenic harm.[10] OSHA has established a ceiling level (not to be exceeded at any time during the workday) of 5 ppm. NIOSH recommends a 15-minute STEL of 1 ppm. The ACGIH TLV for NO_2 is 3 ppm as an 8-hour TWA.

3. <u>Petroleum Hydrocarbons: Toluene and Xylene</u>

   Effects from exposure to refined petroleum solvents are primarily acute, unless significant amounts of substances that have chronic toxicity are present, such as toluene, benzene, or glycol ethers. Epidemiologic studies have shown that exposure to similarly refined petroleum solvents (i.e., mineral spirits, Stoddard solvent) can cause dry throat, burning or tearing of the eyes, mild headaches, dizziness, central nervous system (CNS) depression, respiratory irritation, and dermatitis.[11]

Toluene is a CNS depressant. Low to moderate occupational exposure can cause tiredness, headaches, confusion, memory loss, nausea, and loss of appetite.[10] The NIOSH REL for toluene is 100 ppm for an 8-hour TWA. NIOSH has also set a recommended STEL of 150 ppm for a 15-minute sampling period. The OSHA PEL for toluene is 200 ppm for an 8-hour TWA. The recently adopted ACGIH TLV is 50 ppm for an 8-hour exposure level. This ACGIH TLV carries a skin notation, indicating that cutaneous exposure contributes to the overall absorbed inhalation dose and potential systemic effects.

Exposure to xylene is irritating to the eyes, nose, throat, mucous membranes, and skin. Occupational exposure to xylene has reportedly been known to cause headache, vertigo, stomach, discomfort, and drunkenness. Exposures to high concentrations can causes narcosis.[11] The current OSHA PEL, NIOSH REL, and ACGIH TLV for xylene are 100 ppm over an 8-hour TWA. In addition, NIOSH and ACGIH have published STEL for xylene of 150 ppm averaged over 15 minutes.

The NIOSH REL for total petroleum hydrocarbons mixtures is 350 milligrams per cubic meter of air (mg/m^3) as a full shift TWA exposure, for up to 10 hours per day providing a 40-hour work week is not exceeded. In addition, a ceiling concentration limit (for a 15 minute duration) of 1800 mg/m^3 is recommended by NIOSH. The OSHA PEL for petroleum hydrocarbons is 1600 mg/m^3 TWA, while the PEL for a Stoddard solvent is 525 mg/m^3. The ACGIH has established a TLV-TWA (for 8 hours) of 1600 mg/m^3 for rubber solvent, 1350 mg/m^3 for petroleum hydrocarbons, and 525 mg/m^3 for a Stoddard solvent (and mineral spirits), and a 15-minute STEL of 1800 mg/m^3 for petroleum hydrocarbons.

VI. ENVIRONMENTAL OBSERVATIONS AND RESULTS

Environmental air sampling results are shown in Table I.

Among bus drivers full-shift TWA exposures to CO were measured at 2 ppm, well below the most stringent exposure criteria of 25 ppm which is recommended by the ACGIH. Two 15-minute samples for CO revealed a STEL that peaked at 2.1 ppm, again well below the NIOSH ceiling level of 200 ppm. Full-shift TWA exposures to NO_2 among drivers were none-detected (ND), and one of two 15-minute samples revealed a short-term exposure that peaked at 4.6 ppm. This short-term exposure concentration of 4.6 exceeds the NIOSH STEL of 1 ppm and approaches the OSHA ceiling limit for NO_2 of 5 ppm.

The PBZ air samples from two service lane attendants both measured a TWA exposure to CO of 5.8 ppm, levels which were below the NIOSH REL of 35 ppm, the OSHA PEL of 50 ppm, and the ACGIH TLV of 25 ppm. Full-shift NO_2 exposures among the service lane attendants were both measured at 1.2 ppm, levels which exceeded the NIOSH REL of 1 ppm.

PBZ air samples for hydrocarbons collected on drivers, service lane attendants, and mechanics revealed full-shift TWA total hydrocarbon concentrations that ranged from ND to 1.7 mg/m^3, well below the NIOSH REL of 350 mg/m^3. A 15-minute PBZ air sample for total hydrocarbons measured 14.4 mg/m^3, a concentration below the most stringent STEL of 1800 mg/m^3 recommended by NIOSH. Toluene and xylene were the most predominant individual hydrocarbons measured in the garage storage area and the transmission repair room. Full-shift TWA toluene and xylene exposures peaked at 1.3 and 0.08 ppm, respectively. An area air sample in the transmission repair room revealed a toluene concentration of 0.13 ppm and a xylene concentration of 0.12 ppm, well below their respective TWA exposure criteria of 50 ppm and 100 ppm, respectively.

VII. CONCLUSIONS AND RECOMMENDATIONS

Based on the environmental data and observations obtained during this HHE, service lane attendants and bus drivers were exposed to short-term (15-minute) elevated levels of NO_2. This suggests that diesel exhaust emissions are associated with respiratory irritation reported by Metro Transit workers. In addition, deficiencies were identified at the facility that should be addressed. The following recommendations are offered to correct those deficiencies.

1. On the morning of the evaluation, a visible haze of exhaust emissions was present throughout the storage area. Engine and fuel modifications can reduce the rates of emissions of toxic substances from diesel engines. The assistance of the engine manufacturer representatives should be sought to decrease the rate of exhaust emissions from diesel-powered engines, particularly older models and those considered to be excessive emitters.

2. The performance of the heating, ventilating, and air-conditioning (HVAC) system serving the bus storage area should be evaluated by a qualified ventilation engineer to be certain that it operates as designed by the manufacturer. If it is not, then repairs or modifications should be made to improve ventilation.

3. During the time of the NIOSH evaluation, each bus was equipped with a tailpipe opening located at the lower rear of the bus, approximately 18 inches from ground

level. The position of the tailpipe opening at the lower rear allows diesel emissions to pass through the worker breathing-zone, before being exhausted to the roof outdoors. Management should continue plans to purchase new buses that are equipped with tailpipe openings located at the top of the buses. Buses designed as such will discharge exhaust emissions above the breathing-zone of workers.

4. Several deficiencies discovered in the transmission repair room could result in safety and health problems if they are not corrected. The following recommendations are provided to prevent problems that may arise.

   a. According to the Material Safety Data Sheet (MSDS), the degreaser solvent used in the transmission repair room is extremely flammable and precautions should be taken to prevent accidental fires. The room should be equipped with a fire extinguisher that is suitable for putting out solvent fires (see MSDSs). In addition, hazard communication can be improved by posting warning placards such as "NO SMOKING" and "CAUTION: FLAMMABLE LIQUIDS."

   b. Although the area sample collected in the room revealed an airborne hydrocarbon concentration that was below the NIOSH, OSHA, ACGIH exposure criteria, the result does not include solvent exposures that may occur by way of skin adsorption and ingestion. Both of these routes may contribute to the total body burden of solvent exposure. Repeated or prolonged skin contact with the solvent could result in drying of skin and dermatitis. Gloves made with neoprene (a material which is not resistant to permeation by petroleum hydrocarbon solvents) were reportedly provided for workers who handle transmission parts that are wet with the solvent. Glove materials that offer good permeation resistance to petroleum hydrocarbons include nitrile rubber and fluorocarbon rubber (Viton®).[12] While these glove materials offer better permeation resistance, a glove's resistance to cuts, snags, abrasions, punctures, or tears must also be considered. Another factor is an adequate sleeve (or cuff) length to protect the forearm from solvent exposure. To reduce exposure that may occur by accidental ingestion, workers should be encouraged to practice hand washing after using the degreaser machine.

   c. An eye wash station should be located in the room for accidental cases of solvent splashes in the eyes and face. Training should be provided to inform workers about the presence of an eye wash station and the procedures of using the station in cases of emergencies.

   d. It is not efficient to have the exhaust fan located 10 ft. from the degreaser tank. To more effectively reduce worker exposures to solvent vapors, the degreaser tank and fan should be relocated closer.

e. PBZ air sampling should be conducted by a qualified environmental consultant to assess worker exposure to hydrocarbons while using the degreaser tank. A PBZ sample taken on a worker while using the degreaser tank could be greater than or less than the concentration revealed by the area sample.

VIII. REFERENCES

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1. Metro Transit
2. Amalgamated Transit Union Local 1093
3. OSHA, Region V

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Table I

Air Sampling Results for Diesel Exhaust Components

HETA 93-0633
Metro Transit
Kalamazoo, Michigan
November 30 and December 1, 1993

Sample Description	Time-Weighed Average Concentration				
	Carbon Monoxide (ppm)	**Nitrogen Dioxide (ppm)**	**Toluene (ppm)**	**Xylene (ppm)**	**Total Hydrocarbons (mg/m³)**
Driver†	ND	ND	0.01	0.01	0.13
Driver	--	ND	ND	ND	ND
Driver	2.0	ND	--	--	--
Driver†	2.1	4.6	1.3	ND	14.4
Service Lane Worker #1	5.8	1.2	0.04	0.08	1.7
Service Lane Worker #2	5.8	1.2	0.01	0.02	1.1
Mechanic	--	--	0.01	<0.01	0.14
Area Sample 12 feet from exhaust	39.0	ND	--	--	--
Area Sample in Transmission Room	--	--	0.13	0.12	27.8
NIOSH REL	35 200 (C)	1†	200	100	350 1800 (C)
OSHA PEL	50	5 (C)	100	100	2000
ACGIH TLV	25	3	50	100	1370

ppm = parts per million
mg/m^3 = milligrams per cubic meter
† = short-term exposure measurement
ND = none-detected
C = ceiling