IN DEPTH SURVEY REPORT
OF
Roadway Express, Inc.
Toledo, Ohio

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PURPOSE:	To conduct an in-depth survey of workers' exposures to diesel exhaust. The survey was conducted as part of the Industrywide Studies Branch case control mortality and industrial hygiene study of truck drivers, dock workers and mechanics presumably exposed to diesel exhaust aerosol.
DATE OF SURVEY:	December 19-22, 1988
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SIC CODE:	4231 - Freight Trucking Terminals, with or without maintenance facilities

DISCLAIMER

Mention of facility names or products in this report does not constitute endorsement by the National Institute for Occupational Safety and Health.

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Abstract

The Industrywide Studies Branch of NIOSH is currently conducting a combined case-control mortality and industrial hygiene study of members of the International Brotherhood of Teamsters. The purposes of the study are: 1) to determine whether persons exposed to diesel aerosol as a part of their job continue to have an elevated risk of contracting lung cancer after controlling for tobacco smoking, and 2) to determine relative exposures to diesel aerosol among the four major presumably exposed job groups (road drivers, local drivers, dock workers, and mechanics) identifiable from Teamsters Union records. The second objective was accomplished by conducting a series of industrial hygiene surveys at seven U.S. truck terminals. During each of these surveys, personal and area sampling were conducted to evaluate exposures to submicrometer elemental carbon (used as the principal surrogate marker of exposure), submicrometer organic carbon, and several other particulate and gaseous components of diesel exhaust, including gravimetrically determined respirable dust, polynuclear aromatic hydrocarbons (PAHs), nitro-substituted PAHs, nitrogen dioxide, and nitric oxide.

Elemental carbon sampling results at the Roadway Express, Inc. terminal in Toledo, Ohio during cold weather indicate low-level exposures only slightly above geometric mean ambient residential and highway background concentrations (1.0 ug/m^3 and 2.0 ug/m^3, respectively) in road drivers (2.4 ug/m^3) and local drivers (3.8 ug/m^3), and exposures significantly above background highway concentrations in dock workers (29 ug/m^3), and in mechanics (58 ug/m^3). Mechanics (working in the shop) were found to have the highest mean exposures to elemental carbon, organic carbon, and nitrogen dioxide. Area concentrations of airborne respirable particulate indicated the lowest exposures in road tractor cabs (16.6 ug/m^3), and the highest concentrations in the shop areas (263 ug/m^3). Area concentrations of polynuclear aromatic hydrocarbons (PAHs) and two nitro-PAHs were either not detectable or at trace levels. Exposures to NO, NO_2, and respirable particulate were far below OSHA PELs or NIOSH RELs for these contaminants. The major source of exposures in dock workers appeared to be the operation of diesel-powered fork lift trucks on the dock. The principal source in mechanics was the entry and egress of diesel tractors to and from the shop areas, but the more enclosed environment in which they were working exacerbated concentrations of diesel aerosol.

INTRODUCTION

NIOSH researchers are conducting a study to characterize the current and historical diesel exhaust exposures of trucking industry employees, with the objective of ranking jobs by exposure within the industry. The rankings will be used subsequently in a case-control mortality study to help interpret the results of the study in terms of dose-response, and to correctly classify the study participants by the level of their diesel exhaust exposure. The purpose of the mortality study is to determine if workers in certain jobs in the trucking industry have experienced an increased risk of developing lung cancer compared to presumably non-exposed jobs, after controlling for smoking. The study includes men who died in 1982-83, and applied for a Teamsters Union pension. Thus all persons in the study are long term Teamsters Union members.

One of the difficulties in determining relative exposures to diesel exhaust is deciding what substance or substances to measure. Whole diesel exhaust cannot be measured directly since it is a complex mixture of chemical substances. In addition, many other combustion or pyrolysis products, such as tobacco smoke, industrial aerosols, and wood smoke, contain many of the same components. Several components or fractions of diesel exhaust for which measurement methods have been established include respirable particulate, total airborne particulate, and oxides of nitrogen, sulfur, and carbon (1). In this study, measurement of the elemental carbon content of airborne submicrometer particulate was used as the primary marker of exposure to diesel exhaust.

This report describes the results of an in-depth industrial hygiene survey conducted at the Roadway Express, Inc. break bulk terminal in Toledo, Ohio during the period December 19-22, 1988. During the survey, 66 personal and area samples were obtained for evaluation of workers' exposures to elemental and organic carbon in airborne "submicrometer" aerosol (particles generally smaller than one micrometer in aerodynamic diameter), and 32 personal samples each were obtained for evaluation of workers' exposures to nitrogen dioxide and nitric oxide. Additional area samples were obtained for evaluation of concentrations of airborne respirable dust, elemental and organic carbon content of total airborne particulate, fourteen polynuclear aromatic hydrocarbons (PAHs), and two nitro-substituted PAHs, 1-nitropyrene, and 2-nitrofluorene. This report describes the terminal and its workforce, the toxicity of diesel exhaust and applicable exposure criteria, the methods used during the survey to evaluate diesel exhaust exposures, the results of the sampling, and preliminary conclusions and recommendations.

TRUCK TERMINAL DESCRIPTION

Roadway Express, Inc.'s Toledo terminal is a large break bulk terminal consisting of line-haul (long distance) and city (local area) freight transport, dock, and tractor/trailer repair operations. The facility, opened in 1976, is situated on a 36 acre site on Hagman Street in Toledo, and employs over 900 people. There are two main buildings - the terminal and the garage (repair shop). The truck yard surrounding the dock and offices is asphalt paved. The site currently includes the company's district and terminal offices and a truck/driver dispatching area, and one of the company's largest tractor/trailer maintenance facilities.

Dock Operations

The Toledo dock is typical of break bulk truck docks. The floor of the dock (loading platform) is a concrete slab elevated approximately 3 feet off the ground to allow easy loading and off-loading of truck trailers parked at the doors. The total loading platform floor space is approximately 90,000 square feet. The floor of the dock is essentially an open space, but most floor space, except for the tow-motor (forklift) driving lanes, is normally taken up with materials, hand carts and other moving equipment, and other stock being transferred from one trailer to another within the dock. Two electric conveyor systems, consisting of metal carts pulled on steel tracks by a drag-chain flush-mounted in the concrete floor, are installed on the dock to move material as needed and to supplement the forklift trucks. One of these encircled the south end of the dock, and the other the north end.

The terminal offices are located approximately in the center and on one side of the dock. The dock building itself consists of a prefabricated steel structure with a total of 203 open doors along both sides. Each door is sized larger than the open end of most truck trailers (approximately 10 feet square), again to allow easy access to the interior of the trailer. The doors do not have closures, but during normal dock operations, trailers are parked at many of the door openings.

Ventilation conditions on the dock are essentially the same during both warm or cool weather; i.e., dock doors remain open to the same degree during all weather, and the dock is not heated nor mechanically ventilated. The dock currently operates twenty-four hours per day on seven staggered shifts, but all dock workers work eight-hour shifts.

The terminal currently owns approximately 25-30 Toyota Co. tow-motor trucks. However, only five or six of these are operated on a given shift. All of the tow-motors are diesel-engine powered.

Repair Shop Operations

The terminal's maintenance garage is in a separate building from the main terminal. The repair shop at this site consists of a tractor shop, a safety lane/service area, parts room, lunchroom, shower and locker facilities, and shop offices. The company's district offices are also located on the second floor of this building. The shop offices, parts room, lunchroom, and shower/locker facilities are located between the tractor shop and the safety lanes on the first floor.

The safety lane/service area consists of one large contiguous space divided into several parallel lanes, each lane more than long enough to accommodate a tractor and trailer between the overhead doors at both ends of each lane.

Routine safety checks and services on tractors and trailers are done in this area. The mechanics in charge of these lanes run through a checklist of service/safety items (refueling, oil, brakes, grease, tires, lights, wipers, etc.) to determine the operating condition of the vehicle. Almost all of the road and city tractors undergo this routine service upon arrival at the terminal. The mechanically assisted ventilation system in this area consists of 8-10 (4-5 on each side of the room) rectangular ducts attached to the side walls, with exhaust openings located near the concrete floor. These were designed more for general room ventilation than for control of diesel exhaust. Self-contained, recirculating heating units were also located at intervals near the ceiling throughout the area. During the survey, the exhaust fans were left off, and the bay doors were kept closed due to the cold outside temperatures (approximately 40-45 degree F. daytime highs).

The tractor shop, consisting of a single large room, has two overhead doors (16' x 18'), one at each end, a center driving lane, and eight to ten repair bays 18-20 feet long located at oblique angles to the center lane. The tractor shop does most tuneups, and mechanical, brake, tire, wheel, engine, transmission, and electrical repairs, as well as metal cutting with acetylene torches, and welding. Local exhaust hoods, available at each repair bay, were attached to the trucks' exhaust stacks via flexible tubing if the truck engine remained running while in the shop. According to company personnel, the local exhaust hoods were installed about four years ago (ca 1984). In addition, the shop is fitted with a general room air ventilation system, including three passive louvers located on the two side walls, and tempered makeup air. The heating unit (located in the southwest corner of the room, between the west overhead door and the truck wash rack) was kept running normally during most of the survey, but the large bay doors were kept closed, again due to the cold outside temperatures.

Non-asbestos composition brake linings have been exclusively used since about six to eight years ago, but asbestos composition clutches are still used in the tractor fleet. According to company personnel, mechanics at this facility have cleaned brake drums and clutch housings by washing with a petroleum distillate solvent and rags for at least 15 years. The methods used prior to this time were unknown.

Truck Fleet Description

Roadway's line-haul (road) tractors are not assigned to any one terminal for dispatch or maintenance, but are maintained in a pool for dispatch or maintenance from any one of the district's 10 line-haul terminals. Approximately 3540 of 3800 (about 93%) of Roadway's road tractors are manufactured by White-GMC. These are powered by Detroit Diesel 6V-92, 552 cubic inch diesel engines. In addition, 250 Mack Co. tractors (powered by a Mack Co. diesel engine), 50 Kenworth (Cummins Co. 600 $in.^3$ L10 engine), 50 Freightliner (Cummins Co. L10 engine), and 5 International Harvester Co. tractors (Detroit Diesel 6V-92 engine) are still in use in the road fleet company-wide. All of the road tractors are conventional design (in which the engine is situated in front of the cab, also referred to as "long-nose"), single and double axle tractors, which can haul up to approximately 20,000 or 40,000 lbs. weight, respectively. The fleet is composed of 1984 to 1988 model year trucks. All of the road tractors are currently fitted with vertical ("stack") exhaust systems located on the right side (opposite the driver), over-cab fairings, and air conditioning.

The Toledo terminal has a pool of 14 city tractors, of which 7 are Ford C-800 cab-over designs powered by Detroit Diesel 8.2 L diesel engines. These tractors are fitted with horizontal (undercarriage) exhaust systems. An additional five of the city tractors are Ford model LN8000 conventional design cabs. These five are fitted with vertical stack exhausts, and are powered by the same Detroit Diesel 8.2 L engines. The remaining two city tractors are manufactured by International Harvester Company, and are powered by Detroit Diesel Co. 6V-53 diesel engines. City tractors do not (and have never) had air conditioning installed.

The date of conversion of the road tractor fleet from gasoline engines to diesel was not precisely known, but was estimated to be more than 30 years ago, and was probably complete by the late 1950s. The city tractor fleet was entirely gasoline-engine powered until 1976, at which time conversion to diesel engines began. The conversion of the city fleet to diesel engines is still progressing company wide. Approximately 20 of the 250 city tractors in the district are still gasoline-engine powered. These changes generally are reflective of company-wide changes.

The tractor fleet runs entirely on grade #2 diesel fuel in both summer and winter. In the winter, the company also uses an antigelling additive. Most of the refueling is done at the terminal and is bought in bulk for this purpose. The terminal has a 60000 gallon fuel storage facility on site.

WORKFORCE DESCRIPTION

Approximately 922 persons were, as of the date of the survey, employed at the Toledo terminal. These included about 434 terminal employees, 79 garage employees, 376 road drivers (plus 22 line-haul supervisors) and 11 district managers and staff. The 434 terminal employees included 183 regular dock workers, 112 part-time dock workers ("casuals"), 44 city drivers (including 31 switchers and 13 local drivers - these employees can and do switch frequently between the two jobs), 53 supervisory personnel, and 42 office staff. The garage employed 71 hourly mechanics and 8 shop supervisors. In general, personnel hired as mechanics, city drivers, dock workers, and road drivers remain in that job classification throughout their employment.

The dock operates twenty four hours on seven staggered shifts, but all dock employees work an eight hour shift. The repair shop operates on three eight-hour shifts, 24 hours per day. Road drivers originating at the Toledo terminal are "on-call", but most start their shift in the late afternoon or early evening, which typically lasts 10-12 hours. The terminal is a break bulk or "hub" terminal, in which incoming freight from satellite terminals in the district is consolidated and transferred to another break bulk terminal or to its final destination terminal. Almost all of the local area deliveries and pickups by city drivers are done during daytime hours (8:00 a.m. to about 6:00 p.m.).

MEDICAL, SAFETY, AND INDUSTRIAL HYGIENE PROGRAMS

Safety and Hygiene Programs

The company has no formal in-house industrial hygiene program, but Roadway Express, Inc. has a well developed safety program, with a District Safety Supervisor located at the terminal, as well as a joint union/management safety committee composed of 10-15 people. Safety is considered a distributed primary responsibility of all managers and supervisors, although the terminal manager at each terminal has ultimate responsibility. The program includes extensive new-employee and periodic training programs in safety and hazardous materials, including regular "spill drills", and injury response drills. All employees are required to attend weekly "mini" meetings on safety and hazardous materials issues.

Medical Programs

There is no on-site medical clinic or nurse's station, but the company has an arrangement for medical or emergency care with two nearby clinics and a major hospital. All employees at Roadway are trained in Red Cross first aid, and 30 are also trained in C.P.R. In the case of road drivers, the Department of Transportation requires a pre-employment physical and periodic physicals every two years. The physical is a limited one and includes a medical history, vision tests, hearing and audiometry, and urine tests including a drug screen, specific gravity, albumin, and sugar. All employees (except management) are given a similar pre-employment physical, but except in the case of a return from an injury, no periodic physicals are provided for non-drivers.

DIESEL AEROSOL TOXICOLOGY AND EXPOSURE CRITERIA

Toxic and Carcinogenic Effects

Three characteristics of diesel exhaust particles (DEP) are important in considering the toxicity of diesel exhaust. First, the particles are small and readily inhalable and therefore can reach the lower respiratory system, where they are retained (2). Second, at least several thousand organic compounds can be adsorbed on the surface of the carbon particle aggregates, many of which are cytotoxic, carcinogenic or mutagenic (3). These adsorbed compounds can include polynuclear aromatic hydrocarbons (PAHs), and nitro-substituted PAHs such as 1-nitropyrene and 2-nitrofluorene (4). Third, diesel particles consist largely of carbonaceous material which is relatively stable in biological media. Thus, inhaled diesel particles tend to be retained for long periods in the lower respiratory tract and can accumulate, favoring induction of chronic pulmonary effects such as respiratory impairment and carcinogenesis (4).

Whole diesel exhaust also includes a number of toxic gases or vapors (i.e., various oxides of nitrogen and sulfur, aldehydes, etc.), which appear to play a major role in effects such as acute respiratory irritation. However, it is conceivable that these gases or the organic material adsorbed on deposited particles may play an additive or synergistic role in reducing ciliary clearance as well, perhaps through direct chemical cell toxicity (2).

In a major chronic inhalation study conducted by the Lovelace Institute, rats exposed at a concentration of 350 ug/m^3 DEP for 7 hr/day, 5 days/wk for up to 2 years did not have clearance rates that were significantly different from controls (5). However, rats similarly exposed at a concentration of 7000 ug/m^3 did show clear evidence of pulmonary accumulation of DEP after only 12 months, indicating impaired particle clearance. Rats exposed at concentrations of 3500 ug/m^3 did not demonstrate impaired clearance until after 18 months of exposure. These data suggest that (at least in rats) impairment of pulmonary clearance is a function of both concentration and duration of exposure, and that significant impairment of pulmonary clearance and subsequent accumulation of DEP begins somewhere between a concentration of 350 and 7000 ug/m^3 (0.35 and 7 mg/m^3). However, substantial differences in lung clearance rates between test animals and humans make these data difficult to interpret in terms of human risk assessment (2).

NIOSH recently published a current intelligence bulletin (1) which concluded that "...whole diesel exhaust be regarded as a potential occupational carcinogen in conformance with the OSHA Cancer Policy (29 CFR 1990)". This conclusion was based on the results of recent animal and human epidemiology studies. The studies in rats and mice confirmed the association between induction of lung tumors and exposure to whole diesel exhaust, and especially the particulate phase (5-9). Several recent human epidemiology studies also consistently suggested an association between occupational exposure to whole diesel exhaust and lung cancer (10-12).

The most recent and thorough epidemiological studies were done by Garshick et al. (11,12) in railroad workers. In both of those case control studies, significant excesses of lung cancer were identified in certain age groups of exposed railroad workers, after controlling for tobacco smoking and asbestos exposures. Classification of the workers into exposed and unexposed groups was confirmed using adjusted respirable particulate (ARP) exposure measurements in 39 representative jobs from four U.S. railroads over a 3-year period. The measurements were adjusted by analyses for nicotine from composited filters obtained from each job group (13). Geometric mean exposures to ARP ranged from 17 ug/m^3 for clerks to 134 ug/m^3 for locomotive shop workers. Differences in climate, facilities, equipment, and work practices were found to affect exposures to diesel exhaust (14).

Exposure Criteria

Permissible exposure limits (PELs) promulgated by the Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration (MSHA), and NIOSH recommended exposure limits (RELs), exist for a number of gas/vapor species present in whole diesel exhaust (Table I, reproduced from NIOSH's Current Intelligence Bulletin No. 50 (1). There are essentially no exposure limits (either promulgated as standards or recommended) directly applicable to evaluation of diesel aerosol (particulate phase) exposures. Both OSHA and MSHA have promulgated exposure limits for respirable nuisance (inert or non-toxic) dust for general occupational (5 mg/m^3) and coal-mine environments (2 mg/m^3). However, neither of these standards were intended to apply to diesel exhaust particulate. These standards are roughly comparable to the medium (3.5 mg/m^3) and high (7 mg/m^3) exposure concentrations used in the animal studies reported by Mauderly et al. (5). Thus, it is unlikely that these concentrations represent reasonable exposure limits for human exposure to diesel aerosol. There are also no existing exposure limits for specific PAHs or N-substituted PAHs. Similarly, the OSHA PEL for coal tar pitch volatiles (measured by solvent extraction of collected particulate) is not considered relevant to diesel emissions.

Measurements of the specific compounds mentioned above (and relating the results to published standards and recommendations) will not serve as adequate surrogates for diesel exhaust, nor do they allow an accurate assessment to be made of the effects of factors such as climate, facility design, work practices, and tractor/tow-motor configuration, type, or age. The measurement of submicrometer elemental carbon, which was used in this survey, appears to be a more sensitive and specific surrogate for diesel exhaust than other previously used surrogates. Currently there are no promulgated standards or recommended limits for exposure to submicrometer elemental carbon in whole diesel exhaust.

METHODS

Background

Characterizing worker exposures to diesel exhaust is difficult because of the complex nature of diesel engine emissions. One of the chief difficulties is determining which of the thousands of compounds best serves as an index of diesel exhaust exposure and as an indicator for the expression of adverse health effects. Since measuring each of the compounds in diesel exhaust is obviously impossible, it is necessary to identify a component of whole exhaust which is thought to be related to the health effect of interest. In this study the health effect of interest is lung cancer.

One of the many problems associated with choosing an appropriate air sampling method is the uncertainty about which specific agent or agents are responsible for the mutagenic and carcinogenic properties of diesel aerosol. It has been established in previous research that whole diesel exhaust has low in-vitro mutagenic potency and low in-vivo carcinogenic potency in rats and mice (15). At present, the role of individual diesel components in the etiology of human lung cancer is unknown. However, it has been established that 90% of the mutagenic potency of diesel exhaust appears to be limited to the particulate phase. (16). In addition, although a few animal studies indicate that filtered diesel exhaust (i.e. the gaseous phase) may also be carcinogenic, lung tumor induction in animals has been primarily associated with exposure to the particulate fraction (1). Therefore, it is reasonable to use an index directly related to the particulate, and not gaseous phase, of diesel aerosol.

Several methods have previously been used to measure worker exposures to diesel exhaust. Measurement of ARP (respirable particulate adjusted for the contribution of tobacco smoke by quantitation of nicotine extracted from the same filters) was used in a recently completed exposure study in railroad workers (14). MSHA, the Bureau of Mines (BOM), and NIOSH have measured exposures to diesel aerosol in dieselized coal mines by gravimetric determination of submicrometer particulate, using a custom- designed "dichotomous" sampling cassette (17).

The major problems associated with the use of these methods in the trucking industry include: 1) the relative insensitivity of the gravimetric method (as high as 200 ug/filter), and 2) lack of specificity, since tobacco smoke produces an unknown and potentially large positive bias.

In this study, exposure to submicrometer elemental carbon (Ce) was chosen as the principal marker of exposure to whole diesel exhaust because: 1) it has 100-fold greater sensitivity over the gravimetric method (the limit of detection is on the order of 2 ug/filter); 2) diesel particulate is typically 60-80% elemental carbon (thus the major component of diesel exhaust is measured); and 3) tobacco smoke is almost entirely organic carbon, and should not produce a significant positive bias.

Sampling Strategy

Approximately 8 personal samples for submicrometer Ce and organic carbon (Co) were obtained on each of the two shifts sampled each day. Generally, 3 to 4 personal samples were obtained from both dock workers and road drivers during one shift per day, and an equivalent number of personal samples were obtained from mechanics and local drivers during the other shift. The sampling was conducted for three days (six shifts) beginning with the second shift on December 19, and ending on the first shift on December 22, 1988.

Passive monitors (Palmes tubes) were also placed on most (not all) of the people from each of the four job groups on whom carbon samplers were placed. Both NO_2 and total oxides of nitrogen samplers were placed (side-by-side) in order to measure the workers' exposures to both nitrogen dioxide (NO_2) and nitric oxide (NO).

Additional area sampling was conducted during the survey to measure concentrations of 1) respirable airborne particulate, 2) submicrometer elemental and organic carbon, 3) elemental and organic carbon content in total (not size selected) airborne particulate, and 4) PAHs and nitro-PAHs (see Table II). Two area samples of each of the four types were obtained on each shift, one in each of the two areas sampled; e.g., in the garage and dock areas during both shifts, in city tractor cabs during the day shift, and in road tractor cabs during the second shift. In the case of the tractor cabs, the sampling pumps were placed on the floor of the cab driven by the person (road or city driver) on whom personal samples were obtained for submicrometer elemental carbon. The sampling cassettes were attached to an appropriate location near the dashboard. In the case of the dock and repair shop, the samplers were placed at one strategic location in each area.

Methods and Materials

Worker exposures to submicrometer Ce and Co were determined by obtaining full shift personal samples using a modified dichotomous sampling cassette developed by NIOSH's Division of Respiratory Disease Studies (DRDS) (17), but containing 37 mm Pallflex Corporation QAOT quartz fiber filters instead of 37 mm PVC filters. Battery-operated personal sampling pumps were used to draw air through these cassettes at a flowrate of 4 Lpm. The modification to the DRDS design entailed resizing the inlet diameter to approximately 0.0520" in order to preserve the impaction characteristics (>1 um aerodynamic diameter) when operating the sampler at a flow rate of 4 Lpm instead of the 2 Lpm flow rate used by DRDS. "Total" elemental and organic carbon were measured in the same way, but using a standard, 37 mm open-face polystyrene cassette instead of the dichotomous sampler.

The dichotomous cassette is essentially a single-stage personal cascade impactor, designed to collect submicrometer particles, and to reject supermicrometer (those larger than 1 um) particles. The dichotomous cassette was used in order to exclude, to the extent possible, non- diesel particulate, since almost all diesel particles (about 95%) are smaller than one micrometer (18). All of these samples were obtained for a full shift, since the main problem is sensitivity, not overloading. The limit of detection is about 2 ug/filter, which translates to a concentration of about 1 ug/m^3, assuming a 2 cubic meter air volume.

Subsequent to the survey, the sample filters were submitted to a laboratory for thermal-optical quantitation of elemental and organic carbon (19-20). In the thermal-optical analysis, a 1 x 1.5 cm rectangular portion of the filter (i.e., a "punch") is removed and placed in a furnace. During each of the two major phases of the analysis, the furnace temperature is increased (stepped) several times to drive off the various carbon species in stages, resulting in a carbon species profile, or thermogram. The method is capable of accurate speciation of elemental and organic carbon fractions in deposits on the filter.

Defining the nature of Ce is not a simple matter. Most researchers define it entirely in terms of the method of analysis. However, elemental (as opposed to "organic") carbon has certain fundamental properties which allow its separation and quantitation, including:

- non-volatility in the absence of oxygen, even at high temperatures,
- in small particles, absorbs light of any wavelength,
- chemical inertness to most acids at room temperature,
- insolubility in all solvents, and
- electrical conductivity.

The thermal-optical determination makes good use of the first two of the above properties. In the first major phase of the analysis, the temperature in the furnace is stepped (250 to 680 degrees C.) in the absence of oxygen to drive off the volatile (essentially organic) species of carbon compounds. During this phase, the transmission of a helium-neon laser beam through the filter is monitored to correct for inadvertent pyrolysis (charring) of organic carbon species to elemental carbon. In the second major phase, the furnace temperature is reduced slightly, and then is again stepped (525 to 750 degrees C.), but in a 2% oxygen atmosphere, to oxidize elemental carbon to carbon dioxide. Quantitation is accomplished during both phases by catalytic reduction of carbon dioxide to methane, and detection using flame ionization.

Respirable dust samples were obtained using NIOSH method 0600 (21). This method measures the mass concentration in air of any non-volatile respirable dust, as specified by the American Conference of Governmental Hygienists (22). The samples were collected using a preweighed 37 mm Millipore 5 um pore-size polyvinyl chloride filter held in a polystyrene cassette. The cassette was placed in a 10 mm nylon cyclone, which separates the particles into respirable and non-respirable fractions. Air was drawn through the cyclone/filter at a flowrate of 1.7 Lpm. The filter was post weighed, after reconditioning in the laboratory, to determine the net weight of particulate collected on the filter.

Nitrogen dioxide was determined by NIOSH method 6700 (21), and total oxides of nitrogen by the method of Palmes et al. (23). Both methods employ a passive diffusion monitor generally referred to as a "Palmes tube". In this technique, the NO_2 reacts with triethanolamine (TEA) coated onto three 40x40 per inch mesh stainless steel screens inserted at the closed end of a 2.8 in. long acrylic tube. The NO_2 reacts with the TEA in a diazotization reaction, quantitatively converting the gas to nitrite. The total oxides of nitrogen sampler is similar, but the NO_x species are first oxidized to NO_2 using a chromic acid impregnated glass fiber disc, also inserted at the closed end of the sampler.

In practice, two Palmes tubes were used side-by-side, only one containing the chromic acid disc. The sampler without the chromic acid disc was used to quantitate NO_2, and the other to quantitate NO_x (essentially NO_2 + NO). In use, the monitors were placed side-by-side in the worker's breathing zone, and the bottom end of each monitor was uncapped. At the end of the worker's shift, the bottom end of each tube was recapped. The trapped NO_2 in all cases was determined by colorimetric determination of nitrite. NO was determined as the difference between the NO_x and NO_2 values. The effective sampling range is between 0.13 and 8.5 ug NO_2 per sample (21). The estimated limit of quantitation (LOQ) for this set of samples was reported to be on the order of 0.085 ug per sample.

Concentrations of polynuclear aromatic hydrocarbons (PAHs) and nitro-substituted PAHs (N-PAHs) were determined using NIOSH method 5506 (21). The sampling train consisted of a 37 mm Zefluor^{tm} PTFE filter housed in a polystyrene sampling cassette, followed in line by a glass tube containing washed XAD-2 resin (Orbo-43^{tm} tube). In this method, particulate-phase PAHs were collected on the PTFE membrane filters, and volatile/semivolatile PAHs were collected by the washed XAD-2 resin.

During sampling, air was drawn through the sampling train at a rate of 2 Lpm for approximately eight to ten hours. Prior to sampling, the filter cassette and Orbo-43 tube assembly were wrapped with aluminum foil to prevent ultraviolet (UV) degradation of collected PAHs. After sampling, the filter was transferred to a glass scintillation vial, and both the vial and the recapped Orbo-43 tube were again wrapped in aluminum foil. Samples were kept frozen until analysis by the laboratory. In the laboratory, both filters and resin were desorbed with acetonitrile. Fourteen PAHs and two N-PAHs (2-nitrofluorene and 1-nitropyrene) were determined by high-performance liquid chromatography and quantitated using fluorescence/UV detection.

RESULTS

Figures 1 and 2 are bar charts of the geometric mean concentrations of elemental and organic carbon, by job or area, including the results of the highway and residential area samples obtained for reference. Figures 3, and 4 are similar charts illustrating exposures to nitrogen dioxide (NO_2) and respirable particulate, respectively. Tables III and IV present statistical summaries, by job categories, of those personal samples obtained to evaluate time weighted average exposures to elemental and organic carbon, respectively. Tables V and VI contain statistical summaries of NO_2 and nitric oxide (NO) concentrations by job or area. Table VII is a statistical summary of respirable dust concentrations in four areas. Table VIII is a summary of concentrations of five PAHs found in four sorbent tube samples in the repair shop. Tables 1- 6 in appendix B contain the individual personal, eight-hour, time weighted average exposures to elemental and organic carbon, NO_2, NO, respirable dust, and five PAHs. Concentrations of nine of the fourteen PAHs and the two nitro-PAHs for which sampling was conducted (Table II) are not included in this report because all of the sampling results were below the limit of detection of the analytical method. In the following discussion, the terms "average" and "mean" denote geometric means (not arithmetic), unless indicated otherwise.

Submicrometer Elemental and Organic Carbon

As indicated in Figure 1 and Table III, the geometric mean submicrometer elemental carbon exposures of personnel sampled at this facility ranged from 2.4 ug/m^3 in road drivers to 58 ug/m^3 in mechanics. The intermediate job means were (from low to high - refer to Figure 1): local drivers (3.8 ug/m^3), switchers (6.8 ug/m^3 in a single sample), and dock workers (29 ug/m^3). Area concentrations in four areas averaged 3.0 ug/m^3 in local cabs, 3.4 ug/m^3 in road tractor cabs, 18 ug/m^3 on the dock, and 73 ug/m^3 in the garage area.

By contrast, concentrations measured on a major interstate freeway within Toledo (at the intersection of Alexis Rd. and I-75) averaged 1.97 ug/m^3

(range: 0.48 to 6.44 ug/m^3 in three samples), and in a residential area (at least 1 mile from the nearest major highway) averaged 0.99 ug/m^3 (range: 0.48 to 1.55 ug/m^3 in three samples).

Inspection of Figure 1 indicates that mean exposures to elemental carbon in three jobs, road drivers, local drivers, and switchers, were essentially indistinguishable from highway background concentrations, although local drivers' exposures appeared to be higher than residential concentrations. Exposures of dock workers and mechanics appeared to be significantly above background concentrations (both residential and highway). The 95% upper confidence limits (UCL) of the highway and residential concentrations (Table III) were higher than the 95% lower confidence limit (LCL) of all of the other job means except dock workers and mechanics, suggesting that only dock workers' and mechanics exposures were significantly higher. However, it may be that the sample sizes within individual jobs (N ranging from 3 to 12) were too small to detect a true significant difference. Also, multiple comparisons errors (i.e., comparing more than tow means at a time) make these comparisons only approximate. Thus, final judgement on this conclusion (using factorial analysis of variance) will be reserved until the data from all seven surveys have been pooled and analyzed together.

Concentrations of elemental carbon in total airborne particulate (Table III) were essentially indistinguishable from concentrations of submicrometer elemental carbon obtained in duplicate. Mean concentrations of elemental carbon in these samples ranged from 2.65 ug/m^3 in road cabs to 112 ug/m^3 in the shop area.

Figure 2 and Table IV contain comparable summary statistics for the same samples analyzed for organic carbon. As indicated, geometric mean exposures to submicrometer organic carbon ranged from a low of 19 ug/m^3 in road drivers to a high of 91.6 ug/m^3 in mechanics (a single sample result, obtained on a switcher, 155 ug/m^3 was undoubtedly elevated due to cigarette smoke, since this person was a smoker). Other job means (Table IV and Figure 2) were intermediate to these. Geometric mean area concentrations of organic carbon ranged from 14.2 ug/m^3 on the dock to 73.4 ug/m^3 in the shop area.

Residential area concentrations of submicrometer organic carbon averaged 1.9 ug/m^3, and highway ambient area concentrations averaged 2.2 ug/m^3. The 95% LCLs of personal samples from local drivers, dock workers, and mechanics were higher than the 95% UCL for the highway samples (14.6 ug/m^3), suggesting that their exposures to submicrometer organic carbon were significantly greater than background highway concentrations of organic carbon. Although substantial quantities of organic carbon species can be present in diesel exhaust, this result more likely reflects exposures to other sources of organic carbon, such as tobacco smoke, paint aerosol and solvents, degreasing vapors, and fuel vapors from vehicles (during refueling operations for example). Exposures of road drivers could not be similarly distinguished from background highway concentrations, although they appeared to be higher than residential concentrations.

Oxides of Nitrogen

Nitrogen dioxide (NO_2) concentrations determined in personal samples from 5 jobs (Figure 3 and Table V) ranged from 0.03 ppm (single sample from a switcher) to 0.16 ppm (mechanics). All of the results were far below the OSHA PEL of 5 ppm (ceiling), the NIOSH REL of 1 ppm (15 minute ceiling), or the American Conference of Governmental Industrial Hygienists' Threshold Limit Value (TLV) of 3 ppm (8-hour time-weighted average).

Nitric oxide (NO) exposure means (Figure 4 and Table VI; NO_2 and NO samples were obtained as duplicate samples on the same workers) ranged from 0.01 ppm in road drivers to 0.02 ppm in dock workers. No exposure means or other statistics (other than ranges) were calculated for mechanics or local drivers since the majority of concentrations were below the limit of detection. These exposures are again far below applicable OSHA PELs or NIOSH RELs (Table I).

Respirable Dust

Figure 4 and Table VII summarize concentrations of respirable dust obtained in specific areas of the repair shop, dock, and in local and road tractors. Respirable dust concentrations in road cabs averaged 16.6 ug/m^3, 50.6 ug/m^3 on the dock, 66.2 ug/m^3 in local cabs, and 263 ug/m^3 in the shop area.

Polynuclear Aromatic Hydrocarbons

Table VIII is a summary of concentrations of five PAH compounds found on the XAD-2 sorbent tubes in two areas of the repair shop. Only these five compounds were detectable on any of the samples obtained during the survey on either the filters or the backup sorbent tubes. Detectable concentrations of the remainder of the fourteen PAHs and two nitro-PAHs analyzed (Table II) were not found in this area. In addition, no PAHs or nitro-PAHs were detected in samples obtained in local or road tractor cabs, or on the dock. As indicated, the geometric mean concentrations of the five PAHs ranged from 0.08 ug/m^3 (pyrene) to 1.67 ug/m^3 (phenanthrene). The mean concentration of the total of the five PAHs was 3.6 ug/m^3. Assuming there were in fact no other PAHs present in this area, this value represents approximately 1% of the concentration of respirable dust found in replicate samples obtained in the same area, and approximately 2% of the organic carbon in total particulate obtained in replicate samples from the same areas. Obvious potential sources of these PAHs include either or both diesel exhaust and tobacco smoke.

CONCLUSIONS

1. Based on measurements of personal, breathing zone concentrations of elemental carbon at this terminal, it appears that mechanics' and dock workers' exposures to diesel aerosol were elevated significantly above background highway concentrations found in the Toledo area. The substantially higher exposures of mechanics (relative to other jobs) were very likely due to the more enclosed environment in which they were working. In addition, Dock

workers' high exposures were undoubtedly due to the operation of diesel-powered forklift trucks on the dock, since this was the major source of their exposure. With regard to the other jobs sampled, the lack of demonstrably higher exposures compared with background highway concentrations may be due to a small sample size (and necessarily wide confidence limits), or may be due to the lack of a true difference. Firmer conclusions must await analysis of this data in conjunction with data collected during the remainder of the surveys at other terminals.

2. Geometric mean ambient highway concentrations of submicrometer elemental carbon were, in this survey, slightly higher (but probably not significantly higher) than geometric mean ambient residential concentrations. In addition, road and local drivers' mean exposures to elemental carbon were generally of the same order of magnitude as ambient highway concentrations. Thus, a substantial portion of truck drivers' exposures may have stemmed from ambient (highway) concentrations, rather than from the truck they were driving.

3. Geometric mean organic carbon concentrations were higher than elemental carbon concentrations in most jobs and areas sampled at this terminal, possibly indicating the presence of some non-diesel air contaminants, including paint solvents, degreasing solvent vapors, or tobacco smoke, in the samples. In fact, the generally very low concentrations of submicrometer elemental carbon in most samples, except dock workers and mechanics, suggest that very little if any diesel aerosol was present in these jobs or areas.

4. The mean personal exposures to submicrometer elemental carbon and area concentrations of respirable dust suggested that the lowest exposures to diesel aerosol were in road drivers, and by far the highest were in mechanics.

5. Geometric mean exposures to oxides of nitrogen (NO_2 and NO), and respirable dust were very low, and were far below OSHA PELs and NIOSH RELs for these airborne contaminants.

6. Only five PAHs were detectable (and those only in trace amounts) in area samples obtained in the repair shop. No PAHs or nitro-PAHs were detected in the other three areas sampled (road cabs, local cabs, and the dock). These could have come from either the presence of high concentrations of diesel aerosol (likely) or to the presence of tobacco smoke (unlikely since these were area samples.)

7. Additional data collected during this survey regarding environmental factors (e.g. ambient temperatures), tractor configurations, tractor age, engine size and type, trailer weight, miles driven per shift, presence or absence of air conditioning, and other factors will be consolidated with similar data collected at other terminals and used to help determine the significance of these factors in exposure to diesel exhaust. The data reported here were collected in relatively cold conditions (approximately 40-45 degrees F. daytime highs), and represent tractors with vertical (stack) exhaust systems, and mostly conventional (not cab-over) tractor designs.

RECOMMENDATIONS

In general, exposures to submicrometer elemental carbon were quite low during the survey. The data indicate that overall exposures to whole diesel exhaust in most jobs were only slightly above local ambient highway concentrations. The lone exception, mechanics working in the shop, experienced exposures somewhat higher, by a factor of approximately eight, due mainly to the more enclosed space in which they were working, compared to other jobs. However, in view of the potential carcinogenicity of whole diesel exhaust to humans as documented by NIOSH in its 1988 Current Intelligence Bulletin, the following general recommendations are prudent.

Exposures to diesel exhaust should be reduced to the lowest feasible limits using one or more of the following techniques: source controls, changes in work practices, substitution, and engineering controls such as local and general exhaust ventilation techniques. Source controls would include careful, continued engine maintenance and tune-ups in tow- motors, tractors, and switching vehicles, as well as use of direct exhaust controls such as ceramic filters. Changes in work practices could include planned rotation of workers between jobs to minimize exposures (between work on the dock and driving tractor cabs, for instance). Local exhaust techniques include use of flexible duct vehicle exhaust removal systems in buildings or other enclosed or semi-enclosed spaces such as the repair shop. General (dilution) exhaust and tempered air makeup systems can be useful in controlling exposures in enclosed spaces such as the repair shop, particularly in cold weather, or where it is not possible to effectively control exposure using only local exhaust systems. Substitution would include replacement of older or malfunctioning equipment with newer, more efficient models, or substituting gasoline, electric, or propane powered vehicles for diesel powered vehicles.

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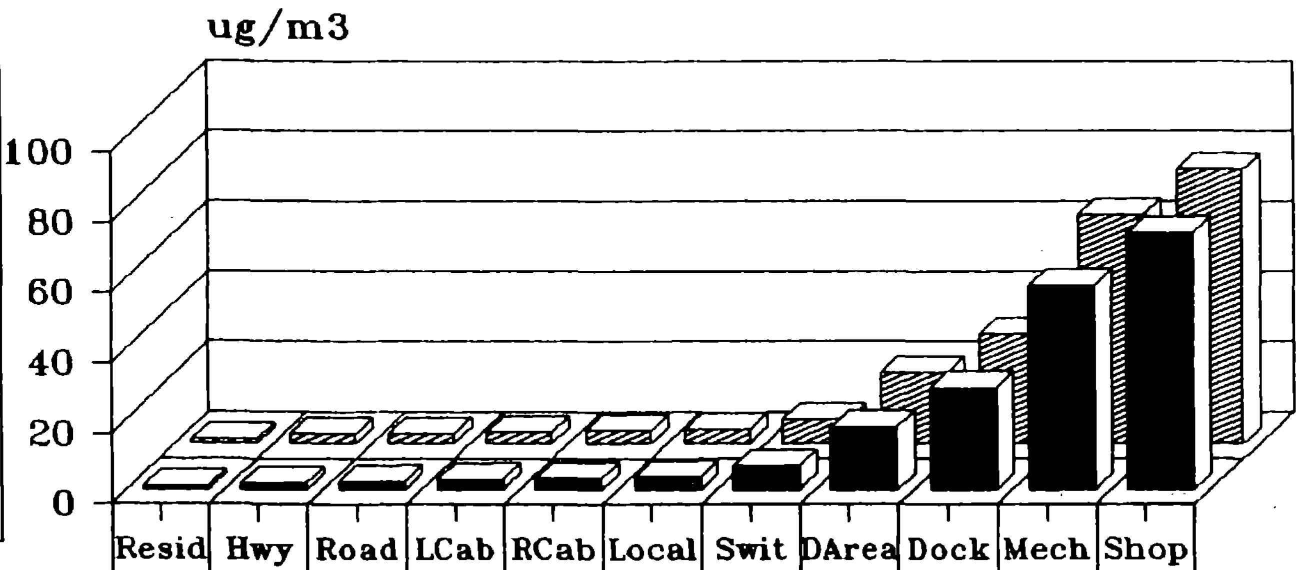
Figure 1. Elemental Carbon Exposure
Roadway Express, Inc.



	Resid	Hwy	Road	LCab	RCab	Local	Swit	DArea	Dock	Mech	Shop
Arithmetic Mean	1.1	2.8	2.7	3.2	3.6	4	6.8	20	31	65	78
Geometric Mean	1	2	2.4	3	3.4	3.8	6.8	18	29	58	73

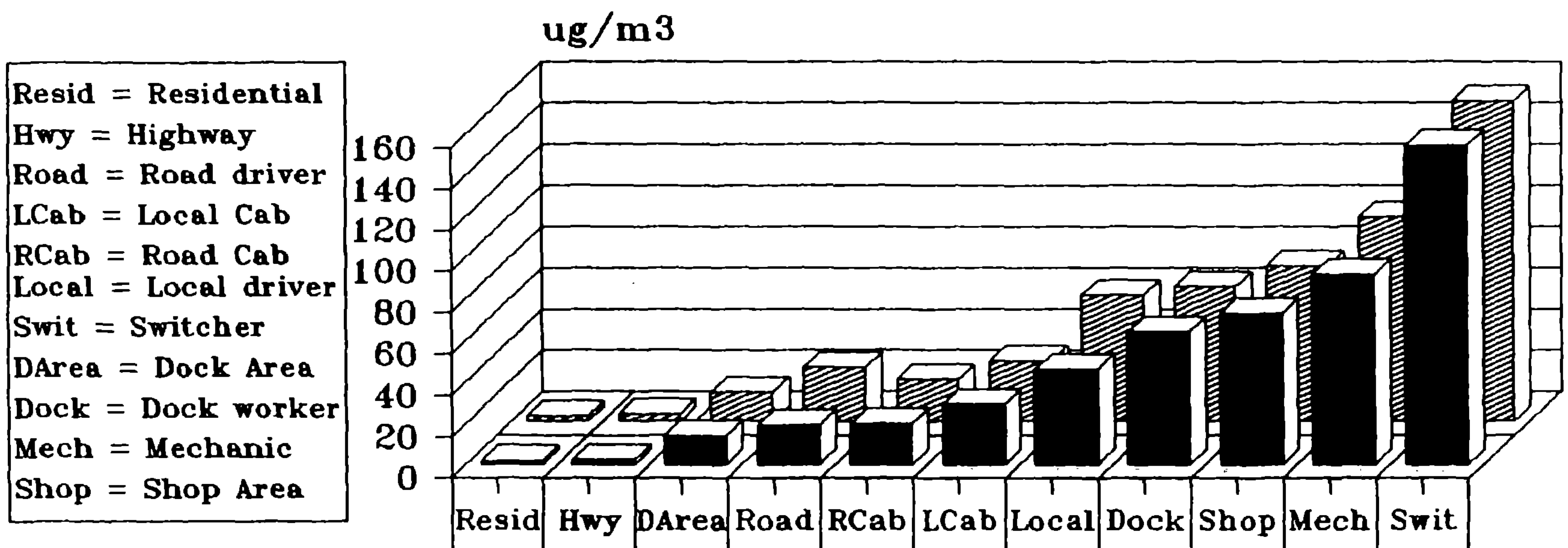
Job/Area

Resid = Residential
Hwy = Highway
Road = Road driver
LCab = Local Cab
RCab = Road Cab
Local = Local driver
Swit = Switcher
DArea = Dock Area
Dock = Dock worker
Mech = Mechanic
Shop = Shop Area

Geometric Mean — Arithmetic Mean

December 1988

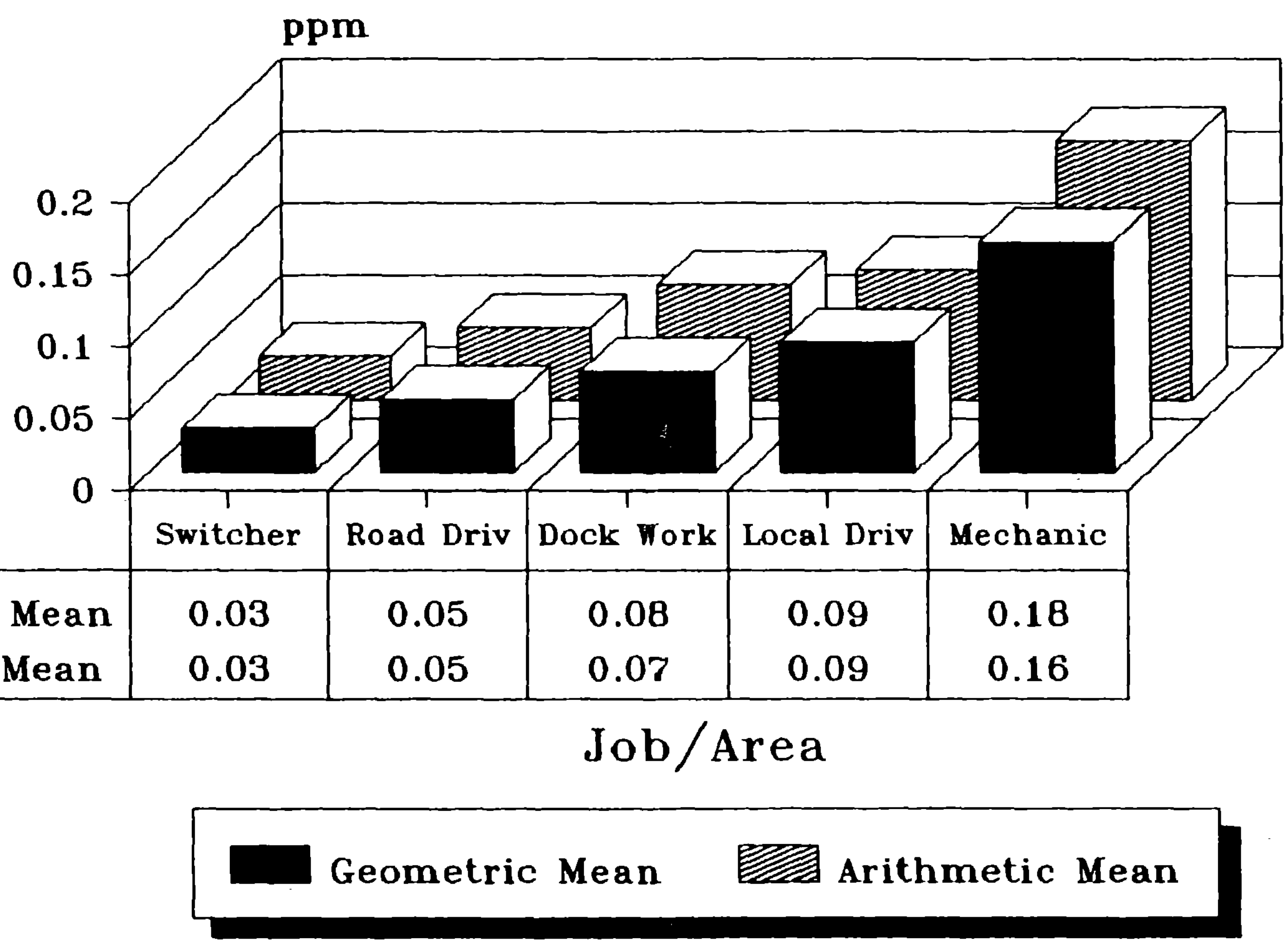
Figure 2. Organic Carbon Exposure Roadway Express, Inc.



	Resid	Hwy	DArea	Road	RCab	LCab	Local	Dock	Shop	Mech	Swit
Arithmetic Mean	2.4	3.5	14	26	20	29	61	65	75	99	155
Geometric Mean	1.9	2.2	14	19	20	29	46	64	73	92	155

December 1988

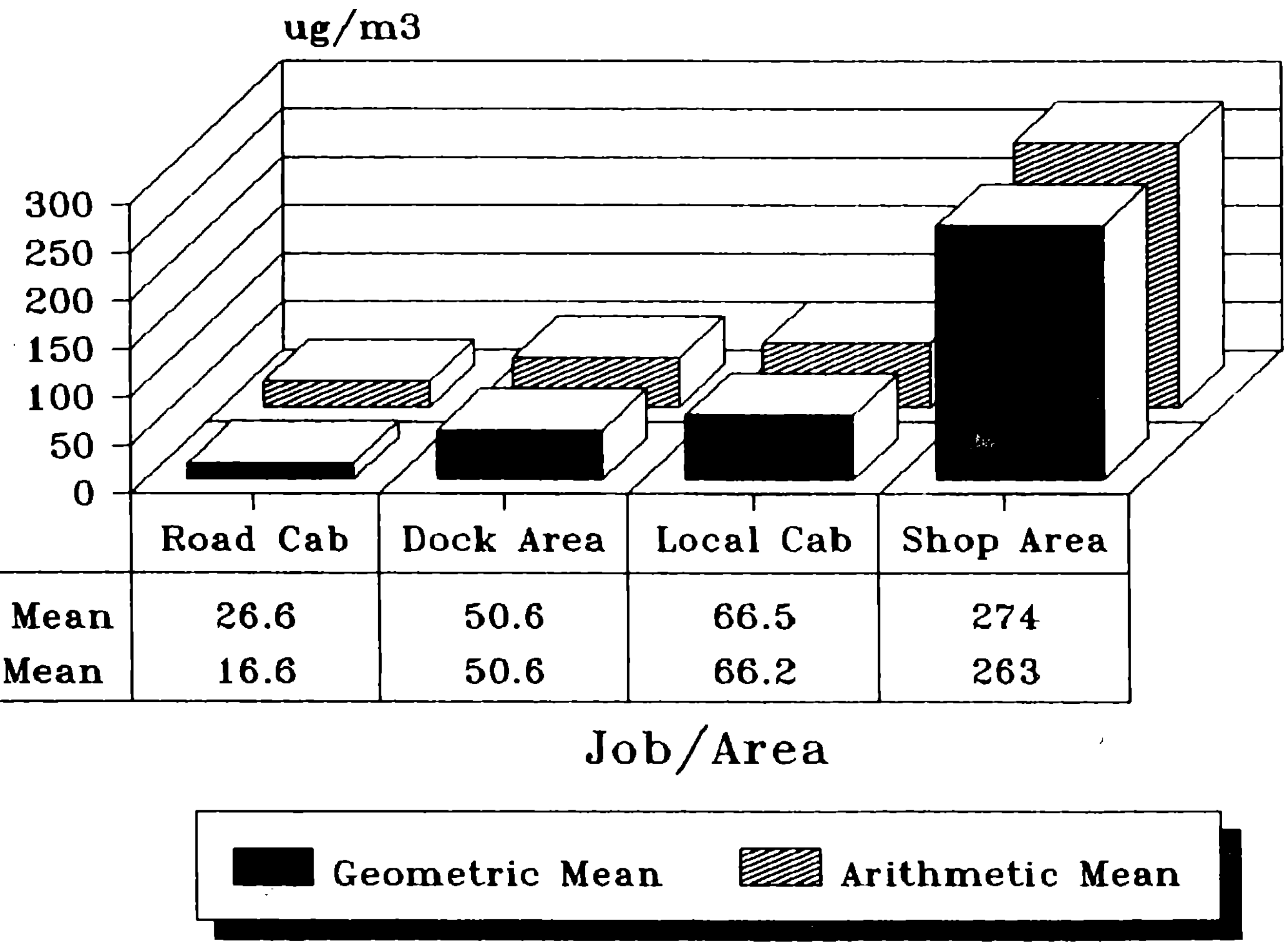
Figure 3. Nitrogen Dioxide Exposure
Roadway Express, Inc.



	Switcher	Road Driv	Dock Work	Local Driv	Mechanic
Arithmetic Mean	0.03	0.05	0.08	0.09	0.18
Geometric Mean	0.03	0.05	0.07	0.09	0.16

December 1988

Figure 4. Respirable Dust Exposure
Roadway Express, Inc.



	Road Cab	Dock Area	Local Cab	Shop Area
Arithmetic Mean	26.6	50.6	66.5	274
Geometric Mean	16.6	50.6	66.2	263

Job/Area

December 1988

Table I.—Limits for occupational exposure to selected components of the gaseous fraction of diesel exhaust; OSHA, MSHA, NIOSH compared

Component	OSHA PEL	MSHA PELs*: Underground coal mines	MSHA PELs*: Metal and nonmetal mines	NIOSH REL
Carbon dioxide (CO_2)	5,000 ppm (9,000 mg/m^3), 8-hr TWA†	5,000 ppm (9,000 mg/m^3), 8-hr TWA; 30,000 ppm (54,000 mg/m^3), STEL§	5,000 ppm (9,000 mg/m^3), 8-hr TWA; 15,000 ppm (27,000 mg/m^3), STEL	10,000 ppm (18,000 mg/m^3), 8-hr TWA; 30,000 ppm (54,000 mg/m^3), 10-min ceiling
Carbon monoxide (CO)	50 ppm (55 mg/m^3), 8-hr TWA	50 ppm (55 mg/m^3), 8-hr TWA; 400 ppm (440 mg/m^3), STEL	50 ppm (55 mg/m^3), 8-hr TWA; 400 ppm (440 mg/m^3), STEL	35 ppm (40 mg/m^3), 8-hr TWA; 200 ppm (230 mg/m^3), ceiling (no minimum time)
Formaldehyde	1 ppm, 8-hr TWA; 2 ppm, 15-minute STEL	1 ppm (1.5 mg/m^3), 8-hr TWA; 2 ppm (3 mg/m^3), STEL	2 ppm (3 mg/m^3), ceiling	0.016 ppm (0.020 mg/m^3), 8-hr TWA; 0.1 ppm (0.12 mg/m^3), 15-min ceiling
Nitrogen dioxide (NO_2)	5 ppm (9 mg/m^3), ceiling	3 ppm (6 mg/m^3), 8-hr TWA; 5 ppm (10 mg/m^3), STEL	5 ppm (9 mg/m^3), ceiling	1 ppm (1.8 mg/m^3), 15-min ceiling
Nitric oxide (NO)	25 ppm (30 mg/m^3), 8-hr TWA	25 ppm (30 mg/m^3), 8-hr TWA	25 ppm (30 mg/m^3), 8-hr TWA; 37.5 ppm (46 mg/m^3), STEL	25 ppm (30 mg/m^3), 10-hr TWA
Sulfur dioxide (SO_2)	5 ppm (13 mg/m^3), 8-hr TWA	2 ppm (5 mg/m^3), 8-hr TWA; 5 ppm (10 mg/m^3), STEL	5 ppm (13 mg/m^3), 8-hr TWA; 20 ppm (52 mg/m^3), STEL (5 min)	0.5 ppm (1.3 mg/m^3), 10-hr TWA

*MSHA limits are based on threshold limit values (TLVs®) of the American Conference of Governmental Industrial Hygienists (ACGIH). 1973 TLVs® are used for metal and nonmetal mines. Current TLVs® are used for underground coal mines.
†Time-weighted average.
§Short-term exposure limit.

Table II
Polycyclic Aromatic Hydrocarbons (PAHs) and Nitro–substituted PAHs ; Detection and Quantitation Limits
Roadway Express, Inc.; December 1988

Name	LOD (ng/tube)	LOD (ng/filter)	LOQ (ng/tube)	LOQ (ng/filter)
Acenaphthene	100	100	300	-
Phenanthrene	50	50	200	-
Anthracene	30	30	100	-
Fluoranthrene	30	30	-	-
Pyrene	30	30	100	80
Benz(a)anthracene	30	30	-	-
Chrysene	30	30	-	-
Benzo(b)fluoranthene	30	30	-	-
Benzo(k)fluoranthene	30	30	-	-
Benzo(e)pyrene	30	30	-	-
Benzo(a)pyrene	30	30	100	100
Indeno(1,2,3–cd)pyrene	30	30	-	-
Dibenz(a,h)anthracene	30	30	-	-
Benzo(ghi)perylene	30	30	-	-
1–nitropyrene	100	100	-	-
2–nitrofluorene	600	200	2000	-

LOD = Limit of Detection
LOQ = Limit of Quantitation

Table III. Elemental Carbon Summary Statistics By Job or Specific Location Roadway Express, Inc. (ug/m3)

Job or Area	N	Min	Max	Arithmetic Mean	Arithmetic S.E.	Geometric Mean	Geometric Std. Dev.	95% Confidence Limit Lower	95% Confidence Limit Upper
Residential	4	0.48	1.55	1.08	0.23	**0.99**	1.67	0.44	2.26
Highway	4	0.48	6.44	2.84	1.27	**1.97**	2.90	0.36	10.8
Road	12	0.50	4.93	2.73	0.36	**2.39**	1.85	1.62	3.52
Local Cab	2	2.11	4.36	3.23	1.13	**3.03**	1.67	0.03	307
Road Cab	4	2.01	4.54	3.61	0.55	**3.45**	1.44	1.92	6.18
Local	9	1.88	5.52	4.05	0.43	**3.83**	1.45	2.89	5.09
Switch	1	6.82	6.82	6.82	--	**6.82**	--	--	--
Dock Area	2	11.4	29.1	20.3	8.86	**18.2**	1.94	0.05	7004
Dock	8	14.7	47.1	30.8	3.58	**29.2**	1.44	21.5	39.6
Mechanic	16	30.4	195	64.5	9.60	**57.8**	1.57	45.4	73.5
Shop Area	4	52.7	132	77.9	18.2	**72.8**	1.50	38.2	139
Elemental Carbon Content of total airborne particulate:									
Road Cab (Total)	3	1.20	4.47	3.04	0.97	**2.65**	2.01	0.47	15.0
Local Cab (Total)	2	3.84	3.87	3.85	0.01	**3.85**	1.00	3.71	4.01
Dock Area (Total)	2	17.1	35.4	26.2	9.13	**24.6**	1.67	0.24	2480
Shop Area (Total)	4	65.0	171	118	21.6	**112**	1.49	59.1	212

Table IV. Organic Carbon Summary Statistics By Job or Specific Location Roadway Express, Inc. (ug/m3)

Job or Area	N	Min	Max	Arithmetic Mean	Arithmetic S.E.	Geometric Mean	Geometric Std. Dev.	95% Confidence Limit Lower	95% Confidence Limit Upper
Residential	4	0.51	3.60	2.36	0.73	**1.9**	2.48	0.44	7.90
Highway	4	0.52	8.53	3.53	1.76	**2.2**	3.25	0.34	14.6
Dock Area	2	12.0	16.8	14.4	2.43	**14.2**	1.27	1.64	123
Road	12	0.53	47.7	26.2	4.1	**19.0**	3.31	8.88	40.6
Road Cab	4	14.5	28.9	20.4	3.04	**19.8**	1.33	12.6	31.1
Local Cab	2	25.2	32.6	28.9	3.70	**28.6**	1.20	5.56	147
Local	9	21.0	133	60.7	16.0	**46.4**	2.13	25.9	83.1
Dock	8	47.5	81.5	65.3	4.65	**64.1**	1.24	53.7	76.5
Shop Area	4	52.1	85.0	74.8	7.63	**73.4**	1.26	50.9	106
Mechanic	16	48.9	217	99.3	11.3	**91.6**	1.49	74.0	113
Switch	1	155	155	155	--	**155**	--	--	--
<u>Organic Carbon content in total Airborne Particulate:</u>									
Dock Area (Total)	2	24.3	34.2	29.2	4.96	**28.8**	1.27	3.26	254
Road Cab (Total)	3	25.9	40.8	32.7	4.32	**32.2**	1.25	18.3	56.5
Local Cab (Total)	2	69.6	82	75.9	6.3	**75.6**	1.13	26.2	219
Shop Area (Total)	4	131	244	188	23.2	**184**	1.29	122	277

Table V. Nitrogen Dioxide Summary Statistics
By Job or Specific Location
Roadway Express, Inc.
(ppm)

Job or Area	N	Min	Max	Arithmetic Mean	Error	Geometric Mean	Std. Dev.	95% Confidence Limit Lower	95% Confidence Limit Upper
Switcher	1	0.03	0.03	0.03	--	**0.03**	--	--	--
Road	8	0.02	0.07	0.05	0.01	**0.05**	1.47	0.04	0.07
Dock	4	0.06	0.10	0.08	0.01	**0.07**	1.31	0.05	0.11
Local	7	0.05	0.15	0.09	0.01	**0.09**	1.40	0.06	0.12
Mechanic	12	0.08	0.33	0.18	0.02	**0.16**	1.50	0.13	0.21

Table VI. Nitric Oxide Summary Statistics
By Job or Specific Location
Roadway Express, Inc.
(ppm)

Job or Area	N	Min	Max	Arithmetic Mean	Error	Geometric Mean	Std. Dev.	95% Confidence Limit Lower	Upper
Dock	4	0.01	0.04	0.02	0.01	**0.02**	1.85	0.01	0.06
Local*	7	<0.01	0.02	--	--	—	--	--	--
Mechanic*	12	<0.01	0.09	--	--	—	--	--	--
Road	8	<0.01	0.04	0.02	0.004	**0.01**	2.47	0.01	0.03
Switcher	1	0.05	0.05	0.05	--	**0.05**	--	--	--

* Statistics not calculated for this job since most sample results were below the limit of detection (<0.01 ug/sample)

Table VII. Respirable Dust Summary Statistics By Job or Specific Location Roadway Express, Inc. (ug/m3)

Job or Area	N	Min	Max	Arithmetic Mean	Arithmetic Error	Geometric Mean	Geometric Std. Dev.	95% Confidence Limit Lower	95% Confidence Limit Upper
Road Cab	3	6.13	61.3	26.6	17.5	**16.6**	3.26	0.88	313
Dock Area	2	49.9	51.3	50.6	0.72	**50.6**	1.02	42.2	60.7
Local Cab	3	61.3	75.8	66.5	4.66	**66.2**	1.12	49.4	88.6
Shop Area	4	170	382	274	43.7	**263**	1.40	154	448

Table VIII. Summary of Concentrations of *Polynuclear Aromatic Hydrocarbons* Roadway Express, Inc. December 1988

Date	Area	Concentration (ug/m3) Acenapthene	Phenanthrene	Anthracene	Fluoranthrene	Pyrene	Total
12-20	Tractor Repair	2.24	2.35	0.26	0.64	0.10	**5.59**
12-20	Safety Lane	0.54	0.93	0.08	0.17	0.06	**1.78**
12-21	Tractor Repair	1.39	1.82	0.16	0.45	0.09	**3.91**
12-21	Tractor Repair	1.63	1.94	0.18	0.5	0.09	**4.34**
Geometric Mean:		1.29	1.67	0.16	0.40	0.08	**3.60**
Arithmetic Mean:		1.45	1.76	0.17	0.44	0.085	**3.91**

Samples obtained in three other areas, and analyzed for 14 PAHs and 2 nitro-PAHs (Table II) indicated concentrations below the limit of detection, which ranged from 0.03 to 0.10 ug/m3, assuming a sampled air volume of one cubic meter. Only the five PAHs indicated in this table were detected in the shop area samples.

Appendix A
Tables 1-6
Individual Sample Results
Roadway Express, Inc.
Toledo, OH

Table 1. Concentrations of Elemental Carbon
Roadway Express Company
December 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
12-20	REC19	Dock	9	15	17	15	3.9	39.0	480	1886	**20.7**
12-20	REC18	Dock	9	10	17	10	3.9	56.4	480	1882	**30.0**
12-20	REC17	Dock	9	12	17	12	4.0	28.2	480	1915	**14.7**
12-20	REC20	Dock	9	18	14	1	3.9	32.1	283	1112	**28.8**
12-21	REC50	Dock	16	11	0	11	4.1	92.9	480	1973	**47.1**
12-21	REC49	Dock	16	10	0	10	4.0	68.0	480	1934	**35.1**
12-21	REC48	Dock	16	7	0	6	3.9	73.7	479	1882	**39.1**
12-21	REC47	Dock	16	5	0	5	4.0	58.7	480	1915	**30.7**
12-20	REC22	Dock Area	9	32	17	32	4.0	56.4	480	1934	**29.1**
12-21	REC52	Dock Area	16	23	0	23	4.0	21.9	480	1915	**11.4**
12-20	RETC4	Dock Area (Total)	9	32	16	35	3.1	45.6	423	1290	**35.4**
12-21	RETC11	Dock Area (Total)	16	21	0	21	3.0	25.0	480	1459	**17.1**
12-19	REC11	Highway	19	13	0	9	4.1	2.4	296	1202	**2.02**
12-20	REC23	Highway	11	14	18	20	4.0	4.1	426	1717	**2.40**
12-21	REC46	Highway	11	46	17	10	3.9	8.2	324	1277	**6.44**
12-22	REC70	Highway	9	52	17	52	4.0	<2.0	480	1930	**<0.97**
12-20	REC15	Local	8	37	16	37	4.0	3.6	480	1934	**1.88**
12-20	REC13	Local	8	40	16	40	4.1	5.4	480	1958	**2.77**
12-21	REC39	Local	8	45	16	15	3.9	9.3	450	1746	**5.35**
12-21	REC37	Local	8	47	17	15	3.9	10.9	508	1981	**5.52**
12-21	REC36	Local	8	44	16	44	4.0	9.2	480	1925	**4.76**
12-22	REC60	Local	8	39	16	39	4.1	7.8	480	1963	**3.95**
12-22	REC62	Local	8	37	16	37	4.0	9.0	480	1934	**4.64**
12-22	REC66	Local	8	35	16	35	4.2	9.5	480	2002	**4.76**
12-22	REC64	Local	8	40	16	40	3.9	5.2	480	1882	**2.78**
12-20	REC21	Local Cab	8	55	16	55	3.9	3.9	480	1862	**2.11**
12-21	REC45	Local Cab	8	53	16	53	3.9	8.2	480	1886	**4.36**
12-21	RETC7	Local Cab (Total)	8	52	17	8	3.1	5.9	496	1533	**3.84**
12-22	RETC13	Local Cab (Total)	8	42	17	48	3.1	6.5	546	1693	**3.87**
12-19	REC2	Mechanic	16	7	23	38	4.0	59.1	451	1799	**32.8**
12-19	REC3	Mechanic	16	9	23	47	3.9	154.3	458	1800	**85.7**
12-19	REC1	Mechanic	16	3	22	24	3.9	45.6	381	1501	**30.4**
12-19	REC4	Mechanic	16	8	23	43	3.9	117.7	455	1761	**66.8**
12-20	REC25	Mechanic	15	50	18	35	3.9	124.3	165	639	**195**
12-20	REC26	Mechanic	16	3	23	37	3.9	124.5	454	1789	**69.6**
12-20	REC28	Mechanic	16	9	23	43	3.9	99.2	454	1757	**56.5**
12-20	REC27	Mechanic	16	6	23	42	4.0	102.3	456	1819	**56.2**

Table 1. Concentrations of Elemental Carbon (Cont'd)
Roadway Express Company
December 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
12-21	REC40	Mechanic	7	37	15	37	4.0	129.6	480	1934	**67.0**
12-21	REC43	Mechanic	7	43	15	43	3.9	86.1	480	1886	**45.6**
12-21	REC41	Mechanic	7	42	15	42	4.0	59.8	480	1934	**30.9**
12-21	REC42	Mechanic	7	41	15	41	3.9	121.8	480	1882	**64.7**
12-22	REC65	Mechanic	7	35	15	35	3.9	151.8	480	1886	**80.5**
12-22	REC63	Mechanic	7	34	15	34	3.9	93.9	480	1862	**50.4**
12-22	REC67	Mechanic	7	32	15	32	4.1	103.8	480	1958	**53.0**
12-22	REC61	Mechanic	7	35	15	35	4.0	91.9	480	1934	**47.5**
12-19	REC12	Residential	6	52	13	18	3.9	2.0	386	1521	**1.29**
12-20	REC24	Residential	7	25	15	25	4.0	3.0	480	1930	**1.55**
12-21	REC35	Residential	6	50	14	50	4.1	<2.0	480	1949	**<0.96**
12-22	REC75	Residential	7	2	15	2	4.0	2.0	480	1934	**1.01**
12-19	REC5	Road	16	10	23	0	4.0	4.9	410	1652	**2.94**
12-19	REC8	Road	20	58	4	58	4.1	3.9	480	1963	**2.00**
12-19	REC7	Road	20	10	4	10	3.9	4.8	480	1872	**2.55**
12-19	REC6	Road	16	11	0	11	4.0	8.4	480	1925	**4.37**
12-20	REC29	Road	16	10	22	52	3.9	4.8	402	1580	**3.02**
12-20	REC32	Road	16	23	23	1	4.1	3.6	398	1612	**2.26**
12-20	REC30	Road	16	13	19	8	4.0	<2.0	175	705	**<2.65**
12-20	REC31	Road	20	26	4	26	4.1	6.1	480	1958	**3.10**
12-21	REC51	Road	20	45	4	45	3.9	3.8	480	1858	**2.06**
12-21	REC56	Road	20	45	4	45	3.9	<2.0	480	1886	**<0.99**
12-21	REC54	Road	16	23	6	2	4.0	16.3	819	3301	**4.93**
12-21	REC59	Road	16	23	0	23	3.9	7.0	480	1891	**3.71**
12-19	REC10	Road Cab	16	32	0	30	4.1	8.8	478	1936	**4.54**
12-20	REC33	Road Cab	16	22	0	22	4.2	4.0	480	2002	**2.01**
12-21	REC55	Road Cab	20	52	4	52	4.1	7.5	480	1944	**3.85**
12-22	REC69	Road Cab	20	42	4	42	3.9	7.5	480	1858	**4.03**
12-19	RETC2	Road Cab (Total)	16	32	0	32	3.1	5.1	480	1483	**3.47**
12-20	RETC6	Road Cab (Total)	16	24	2	28	3.1	2.2	604	1872	**1.20**
12-21	RETC10	Road Cab (Total)	20	52	4	52	3.1	6.5	480	1464	**4.47**
12-19	REC9	Shop Area	16	43	23	48	3.9	216.9	425	1645	**132**
12-20	REC34	Shop Area	16	37	23	54	4.1	112.7	437	1796	**62.8**
12-21	REC44	Shop Area	9	25	17	25	4.1	126.3	480	1958	**64.5**
12-22	REC68	Shop Area	7	47	15	47	3.9	99.4	480	1886	**52.7**
12-19	RETC1	Shop Area (Total)	16	43	23	48	3.1	224.7	425	1318	**171**
12-20	RETC5	Shop Area (Total)	16	36	23	56	3.0	163.0	440	1338	**122**

Table 1. Concentrations of Elemental Carbon (Cont'd)
Roadway Express Company
December 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
12-21	RETC8	Shop Area (Total)	9	25	17	31	3.0	167.7	486	1448	**116**
12-22	RETC12	Shop Area (Total)	7	50	16	47	3.1	107.9	537	1659	**65.0**
12-21	REC38	Switch	9	1	14	46	4.1	9.6	345	1411	**6.82**

Table 2. Concentrations of Organic Carbon
Roadway Express Company
December 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
12-20	REC19	Dock	9	15	17	15	3.9	143.3	480	1886	**75.9**
12-20	REC18	Dock	9	10	17	10	3.9	89.3	480	1882	**47.5**
12-20	REC17	Dock	9	12	17	12	4.0	134.4	480	1915	**70.2**
12-20	REC20	Dock	9	18	14	1	3.9	54.7	283	1112	**49.2**
12-21	REC50	Dock	16	11	0	11	4.1	137.7	480	1973	**69.8**
12-21	REC49	Dock	16	10	0	10	4.0	144.3	480	1934	**74.6**
12-21	REC48	Dock	16	7	0	6	3.9	153.5	479	1882	**81.5**
12-21	REC47	Dock	16	5	0	5	4.0	103.5	480	1915	**54.1**
12-20	REC22	Dock Area	9	32	17	32	4.0	32.6	480	1934	**16.8**
12-21	REC52	Dock Area	16	23	0	23	4.0	23.0	480	1915	**12.0**
12-20	RETC4	Dock Area (Total)	9	32	16	35	3.1	44.1	423	1290	**34.2**
12-21	RETC11	Dock Area (Total)	16	21	0	21	3.0	35.4	480	1459	**24.3**
12-19	REC11	Highway	19	13	0	9	4.1	10.2	296	1202	**8.53**
12-20	REC23	Highway	11	14	18	20	4.0	3.0	426	1717	**1.72**
12-21	REC46	Highway	11	46	17	10	3.9	4.3	324	1277	**3.34**
12-22	REC70	Highway	9	52	17	52	4.0	<2.0	480	1930	**<1.04**
12-20	REC15	Local	8	37	16	37	4.0	49.0	480	1934	**25.4**
12-20	REC13	Local	8	40	16	40	4.1	53.4	480	1958	**27.3**
12-21	REC39	Local	8	45	16	15	3.9	231.1	450	1746	**132**
12-21	REC37	Local	8	47	17	15	3.9	69.0	508	1981	**34.9**
12-21	REC36	Local	8	44	16	44	4.0	256.8	480	1925	**133**
12-22	REC60	Local	8	39	16	39	4.1	82.5	480	1963	**42.0**
12-22	REC62	Local	8	37	16	37	4.0	49.4	480	1934	**25.5**
12-22	REC66	Local	8	35	16	35	4.2	208.2	480	2002	**104**
12-22	REC64	Local	8	40	16	40	3.9	39.5	480	1882	**21.0**
12-20	REC21	Local Cab	8	55	16	55	3.9	60.6	480	1862	**32.6**
12-21	REC45	Local Cab	8	53	16	53	3.9	47.5	480	1886	**25.2**
12-21	RETC7	Local Cab (Total)	8	52	17	8	3.1	106.6	496	1533	**69.6**
12-22	RETC13	Local Cab (Total)	8	42	17	48	3.1	139.2	546	1693	**82.2**
12-19	REC2	Mechanic	16	7	23	38	4.0	133.8	451	1799	**74.4**
12-19	REC3	Mechanic	16	9	23	47	3.9	126.5	458	1800	**70.3**
12-19	REC1	Mechanic	16	3	22	24	3.9	114.9	381	1501	**76.6**
12-19	REC4	Mechanic	16	8	23	43	3.9	233.9	455	1761	**133**
12-20	REC25	Mechanic	15	50	18	35	3.9	115.2	165	639	**180**
12-20	REC26	Mechanic	16	3	23	37	3.9	109.1	454	1789	**61.0**
12-20	REC28	Mechanic	16	9	23	43	3.9	132.8	454	1757	**75.6**
12-20	REC27	Mechanic	16	6	23	42	4.0	212.8	456	1819	**117**

Table 2. Concentrations of Organic Carbon (Cont'd)
Roadway Express Company
December 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
12-21	REC40	Mechanic	7	37	15	37	4.0	181.8	480	1934	**94.0**
12-21	REC43	Mechanic	7	43	15	43	3.9	190.7	480	1886	**101**
12-21	REC41	Mechanic	7	42	15	42	4.0	94.6	480	1934	**48.9**
12-21	REC42	Mechanic	7	41	15	41	3.9	170.7	480	1882	**90.7**
12-22	REC65	Mechanic	7	35	15	35	3.9	194.2	480	1886	**103**
12-22	REC63	Mechanic	7	34	15	34	3.9	105.8	480	1862	**56.8**
12-22	REC67	Mechanic	7	32	15	32	4.1	173.7	480	1958	**88.7**
12-22	REC61	Mechanic	7	35	15	35	4.0	420.6	480	1934	**217**
12-19	REC12	Residential	6	52	13	18	3.9	5.5	386	1521	**3.60**
12-20	REC24	Residential	7	25	15	25	4.0	3.6	480	1930	**1.87**
12-21	REC35	Residential	6	50	14	50	4.1	<2.0	480	1949	**<1.03**
12-22	REC75	Residential	7	2	15	2	4.0	6.7	480	1934	**3.46**
12-19	REC5	Road	16	10	23	0	4.0	25.7	410	1652	**15.5**
12-19	REC8	Road	20	58	4	58	4.1	38.1	480	1963	**19.4**
12-19	REC7	Road	20	10	4	10	3.9	41.3	480	1872	**22.1**
12-19	REC6	Road	16	11	0	11	4.0	32.4	480	1925	**16.8**
12-20	REC29	Road	16	10	22	52	3.9	68.9	402	1580	**43.6**
12-20	REC32	Road	16	23	23	1	4.1	75.0	398	1612	**46.5**
12-20	REC30	Road	16	13	19	8	4.0	24.1	175	705	**34.1**
12-20	REC31	Road	20	26	4	26	4.1	41.0	480	1958	**20.9**
12-21	REC51	Road	20	45	4	45	3.9	35.1	480	1858	**18.9**
12-21	REC56	Road	20	45	4	45	3.9	<2.0	480	1886	**<1.06**
12-21	REC54	Road	16	23	6	2	4.0	92.9	819	3301	**28.1**
12-21	REC59	Road	16	23	0	23	3.9	90.3	480	1891	**47.7**
12-19	REC10	Road Cab	16	32	0	30	4.1	35.8	478	1936	**18.5**
12-20	REC33	Road Cab	16	22	0	22	4.2	29.0	480	2002	**14.5**
12-21	REC55	Road Cab	20	52	4	52	4.1	38.3	480	1944	**19.7**
12-22	REC69	Road Cab	20	42	4	42	3.9	53.6	480	1858	**28.9**
12-19	RETC2	Road Cab (Total)	16	32	0	32	3.1	60.4	480	1483	**40.8**
12-20	RETC6	Road Cab (Total)	16	24	2	28	3.1	48.6	604	1872	**25.9**
12-21	RETC1(	Road Cab (Total)	20	52	4	52	3.1	46.1	480	1464	**31.5**
12-19	REC9	Shop Area	16	43	23	48	3.9	134.2	425	1645	**81.6**
12-20	REC34	Shop Area	16	37	23	54	4.1	93.5	437	1796	**52.1**
12-21	REC44	Shop Area	9	25	17	25	4.1	157.7	480	1958	**80.5**
12-22	REC68	Shop Area	7	47	15	47	3.9	160.4	480	1886	**85.0**
12-19	RETC1	Shop Area (Total)	16	43	23	48	3.1	172.1	425	1318	**131**
12-20	RETC5	Shop Area (Total)	16	36	23	56	3.0	261.5	440	1338	**196**

Table 2. Concentrations of Organic Carbon (Cont'd)
Roadway Express Company
December 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
12-21	RETC8	Shop Area (Total)	9	25	17	31	3.0	352.9	486	1448	**244**
12-22	RETC12	Shop Area (Total)	7	50	16	47	3.1	304.8	537	1659	**184**
12-21	REC38	Switch	9	1	14	46	4.1	218.2	345	1411	**155**

Table 3. Concentrations of Nitrogen Dioxide
Roadway Express, Inc.
December 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Mass (ug NO2)	Mass (nmoles)	Time (hr)	Concentration (ppm NO2)
12-20	REN2-15	Dock	9	15	17	25	0.1	1.13	8.2	**0.06**
12-20	REN2-14	Dock	9	10	17	25	0.12	1.57	8.3	**0.08**
12-20	REN2-13	Dock	9	12	17	25	0.1	1.13	8.2	**0.06**
12-20	REN2-16	Dock	9	18	15	52	0.12	1.57	6.6	**0.10**
12-20	REN2-9	Local	8	40	17	27	0.14	2.00	8.8	**0.10**
12-20	REN2-10	Local	8	45	18	43	0.12	1.57	10.0	**0.07**
12-20	REN2-11	Local	8	37	17	45	0.1	1.13	9.1	**0.05**
12-20	REN2-12	Local	8	44	17	14	0.13	1.78	8.5	**0.09**
12-21	REN2-25	Local	8	44	17	45	0.15	2.22	9.0	**0.11**
12-21	REN2-28	Local	8	45	16	30	0.17	2.65	7.8	**0.15**
12-21	REN2-26	Local	8	47	17	15	0.11	1.35	8.5	**0.07**
12-19	REN2-1	Mechanic	16	3	23	40	0.11	1.35	7.6	**0.08**
12-19	REN2-4	Mechanic	16	8	23	43	0.17	2.65	7.6	**0.15**
12-19	REN2-2	Mechanic	16	7	23	35	0.22	3.74	7.5	**0.22**
12-19	REN2-3	Mechanic	16	9	23	46	0.16	2.43	7.6	**0.14**
12-20	REN2-17	Mechanic	15	50	23	37	0.16	2.43	7.8	**0.14**
12-20	REN2-20	Mechanic	16	9	23	43	0.19	3.09	7.6	**0.18**
12-20	REN2-18	Mechanic	16	3	23	39	0.16	2.43	7.6	**0.14**
12-20	REN2-19	Mechanic	16	6	23	43	0.16	2.43	7.6	**0.14**
12-21	REN2-29	Mechanic	7	37	15	43	0.26	4.61	8.1	**0.25**
12-21	REN2-32	Mechanic	7	43	15	45	0.14	2.00	8.0	**0.11**
12-21	REN2-30	Mechanic	7	42	15	45	0.33	6.13	8.1	**0.33**
12-21	REN2-31	Mechanic	7	41	15	43	0.26	4.61	8.0	**0.25**
12-19	REN2-5	Road	16	10	23	2	0.066	0.39	6.9	**0.02**
12-19	REN2-8	Road	20	58	5	34	0.079	0.67	8.6	**0.03**
12-19	REN2-6	Road	16	11	22	0	0.092	0.96	5.8	**0.07**
12-19	REN2-7	Road	20	10	4	50	0.089	0.89	8.7	**0.04**
12-20	REN2-21	Road	16	10	22	55	0.096	1.04	6.8	**0.07**
12-20	REN2-23	Road	20	23	8	0	0.1	1.13	11.6	**0.04**
12-20	REN2-22	Road	16	13	2	28	0.11	1.35	10.3	**0.06**
12-20	REN2-24	Road	20	26	2	30	0.094	1.00	6.1	**0.07**
12-21	REN2-27	Switcher	9	1	14	40	0.066	0.39	5.7	**0.03**

Table 4. Concentrations of Nitric Oxide
Roadway Express, Inc.
December 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Mass (ug NOx)	Conc NO2 (ppm)	Mass (nmoles)	Time (hr)	Concentration (ppm NO)
12-20	REN2-15	Dock	9	15	17	25	0.073	0.06	1.59	8.17	**0.02**
12-20	REN2-14	Dock	9	10	17	25	0.113	0.08	2.46	8.25	**0.04**
12-20	REN2-13	Dock	9	12	17	25	0.063	0.06	1.37	8.22	**0.01**
12-20	REN2-16	Dock	9	18	15	52	0.103	0.10	2.24	6.57	**0.03**
12-20	REN2-9	Local	8	40	17	27	0.034	0.10	0.74	8.78	**<0.01**
12-20	REN2-10	Local	8	45	18	43	0.063	0.07	1.37	9.97	**<0.01**
12-20	REN2-11	Local	8	37	17	45	0.031	0.05	0.67	9.13	**<0.01**
12-20	REN2-12	Local	8	44	17	14	0.053	0.09	1.15	8.50	**<0.01**
12-21	REN2-25	Local	8	44	17	45	0.073	0.11	1.59	9.02	**<0.01**
12-21	REN2-28	Local	8	45	16	30	0.083	0.15	1.80	7.75	**<0.01**
12-21	REN2-26	Local	8	47	17	15	0.073	0.07	1.59	8.47	**0.01**
12-19	REN2-1	Mechanic	16	3	23	40	0.113	0.08	2.46	7.62	**0.05**
12-19	REN2-4	Mechanic	16	8	23	43	0.133	0.15	2.89	7.58	**0.01**
12-19	REN2-2	Mechanic	16	7	23	35	0.103	0.22	2.24	7.47	**<0.01**
12-19	REN2-3	Mechanic	16	9	23	46	0.093	0.14	2.02	7.62	**<0.01**
12-20	REN2-17	Mechanic	15	50	23	37	0.103	0.14	2.24	7.78	**<0.01**
12-20	REN2-20	Mechanic	16	9	23	43	0.103	0.18	2.24	7.57	**<0.01**
12-20	REN2-18	Mechanic	16	3	23	39	0.093	0.14	2.02	7.60	**<0.01**
12-20	REN2-19	Mechanic	16	6	23	43	0.123	0.14	2.67	7.62	**0.01**
12-21	REN2-29	Mechanic	7	37	15	43	0.193	0.25	4.20	8.10	**<0.01**
12-21	REN2-32	Mechanic	7	43	15	45	0.003	0.11	0.07	8.03	**<0.01**
12-21	REN2-30	Mechanic	7	42	15	45	0.073	0.33	1.59	8.05	**<0.01**
12-21	REN2-31	Mechanic	7	41	15	43	0.143	0.25	3.11	8.03	**<0.01**
12-19	REN2-5	Road	16	10	23	2	0.027	0.02	0.59	6.87	**0.01**
12-19	REN2-8	Road	20	58	5	34	0.073	0.03	1.59	8.60	**0.04**
12-19	REN2-6	Road	16	11	22	0	0.063	0.07	1.37	5.82	**0.02**
12-19	REN2-7	Road	20	10	4	50	0.063	0.04	1.37	8.67	**0.02**
12-20	REN2-21	Road	16	10	22	55	0.044	0.07	0.96	6.75	**<0.01**
12-20	REN2-23	Road	20	23	8	0	0.093	0.04	2.02	11.62	**0.03**
12-20	REN2-22	Road	16	13	2	28	0.073	0.06	1.59	10.25	**0.01**
12-20	REN2-24	Road	20	26	2	30	0.032	0.07	0.70	6.07	**<0.01**
12-21	REN2-27	Switcher	9	1	14	40	0.053	0.03	1.15	5.65	**0.05**

Table 5. Concentrations of Respirable Dust
Roadway Express, Inc.
December 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentratio (ug/m3)
12-20	FW4379	Dock Area	9	32	17	32	1.7	40	480	802	**49.9**
12-21	FW4383	Dock Area	16	24	0	19	1.6	40	475	779	**51.3**
12-20	FW4378	Local Cab	8	53	16	53	1.7	60	480	792	**75.8**
12-21	FW4381	Local Cab	8	53	16	53	1.7	50	480	816	**61.3**
12-22	FW4385	Local Cab	8	42	16	42	1.7	50	480	802	**62.4**
12-19	FW4695	Road Cab	16	32	0	32	1.7	10	480	816	**12.3**
12-20	FW4694	Road Cab	16	23	0	23	1.7	-10	480	816	**<12.3**
12-21	FW4382	Road Cab	20	52	4	52	1.7	50	480	816	**61.3**
12-19	FW4349	Shop Area	16	43	23	41	1.7	120	418	706	**170**
12-20	FW4182	Shop Area	16	37	23	53	1.7	210	436	737	**285**
12-21	FW4380	Shop Area	9	25	17	25	1.7	310	480	811	**382**
12-22	FW4384	Shop Area	7	48	15	48	1.7	210	480	816	**257**

Table 6. Concentrations of Polynuclear Aromatic Hydrocarbons Roadway Express, Inc. December 1988

Date	Sample Number	Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Conc. (ug/m3)
Acenaphthene											
12-20	REP-1A	Tractor Repair	16	37	23	55	2.0	2	438	894	**2.24**
12-20	REP-2A	Safety Lane	16	41	23	48	2.0	0.45	427	837	**0.54**
12-21	REP-3A	Tractor Repair	9	25	17	3	2.0	1.3	458	934	**1.39**
12-22	REP-11A	Tractor Repair	7	49	15	49	2.0	1.6	480	979	**1.63**
Phenanthrene											
12-20	REP-1A	Tractor Repair	16	37	23	55	2.0	2.1	438	894	**2.35**
12-20	REP-2A	Safety Lane	16	41	23	48	2.0	0.78	427	837	**0.93**
12-21	REP-3A	Tractor Repair	9	25	17	3	2.0	1.7	458	934	**1.82**
12-22	REP-11A	Tractor Repair	7	49	15	49	2.0	1.9	480	979	**1.94**
Anthracene											
12-20	REP-1A	Tractor Repair	16	37	23	55	2.0	0.23	438	894	**0.26**
12-20	REP-2A	Safety Lane	16	41	23	48	2.0	0.07	427	837	**0.08**
12-21	REP-3A	Tractor Repair	9	25	17	3	2.0	0.15	458	934	**0.16**
12-22	REP-11A	Tractor Repair	7	49	15	49	2.0	0.18	480	979	**0.18**
Fluoranthene											
12-20	REP-1A	Tractor Repair	16	37	23	55	2.0	0.57	438	894	**0.64**
12-20	REP-2A	Safety Lane	16	41	23	48	2.0	0.14	427	837	**0.17**
12-21	REP-3A	Tractor Repair	9	25	17	3	2.0	0.42	458	934	**0.45**
12-22	REP-11A	Tractor Repair	7	49	15	49	2.0	0.49	480	979	**0.50**
Pyrene											
12-20	REP-1A	Tractor Repair	16	37	23	55	2.0	0.09	438	894	**0.10**
12-20	REP-2A	Safety Lane	16	41	23	48	2.0	0.05	427	837	**0.06**
12-21	REP-3A	Tractor Repair	9	25	17	3	2.0	0.08	458	934	**0.09**
12-22	REP-11A	Tractor Repair	7	49	15	49	2.0	0.09	480	979	**0.09**

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

An in depth survey was conducted at Roadway Express, Inc. (SIC-4231), Toledo, Ohio determine relative exposures to diesel aerosol among the four major presumably exposed job groups of road drivers, local drivers, dock workers, and mechanics. Element carbon sampling results at the Roadway terminal in Toledo, Ohio, during cold weather indicated low level exposures only slightly above geometric mean ambient residential and highway background concentrations in road drivers and local drivers. Exposures were significantly above background highway concentrations in dock workers and in mechanics, with exposures of 29 and 58 micrograms/cubic meter (microg/m3), respectively. The highest levels of exposure were to mechanics working in the shop. Area concentrations of airborne respirable particulates indicated the lowest exposures in road tractor cabs, 16.6microg/m3, and the highest concentrations in the shop areas of 263 microg/m3. Area concentrations of polynuclear aromatic hydrocarbons and two nitro polynuclear aromatic hydrocarbons were either not detectable or at trace levels. Exposure to nitrogen oxides and respirable particulates were far below recommended limits. The major source of exposures in dock workers appeared to be the operation of diesel powered fork lift trucks on the dock. The principal source in mechanics was the entry and egress of diesel tractors to and from the shop area, but the more enclosed environment in which they were working exacerbated concentrations of diesel aerosols.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms NIOSH-Publication, NIOSH-Author, NIOSH-Survey, Field-Study, Region-5, IWS-146-22, Fuels, Diesel-exhausts, Diesel-emissions, Airborne-particles, Diesel-engines, Automobile-repair-shops, Toxic-gases

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