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16. Abstract (Limit: 200 words) An in depth survey of exposures to diesel exhaust was conducted at the Advance Transportation Company (SIC-4231) terminal in Milwaukee, Wisconsin. The four major presumably exposed job groups were road drivers, local drivers, dock workers, and mechanics. Elemental carbon (7440440) sampling results at the terminal in Milwaukee, Wisconsin during cold weather indicated low level exposure about equal to geometric mean ambient highway and residential background concentrations: 1.3 micrograms/cubic meter (microg/m3) in dock workers; exposures slightly above highway concentrations in local drivers, 2.4 microg/m3, and road drivers, 2.7 microg/m3; and exposure significantly above background highway concentrations for mechanics, 10.7 microg/m3. The highest exposures to elemental carbon, organic carbon, nitrogen-dioxide (10102440), nitric-oxide (10102439), and respirable dust were noted among mechanics working in the shop. Area concentrations of airborne respirable particulates indicated the same relative ranking of jobs suggested by exposures to elemental carbon. Exposures to the nitrogen oxides and respirable particulates were significantly lower than the recommended limits.

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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:	November 28- December 1, 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 Advance Transportation Company terminal in Milwaukee, Wisconsin during cold weather indicate low-level exposures approximately equal to geometric mean ambient highway and residential background concentrations (both 1.3 ug/m^3) in dock workers (1.3 ug/m^3), exposures slightly above highway concentrations in local drivers (2.4 ug/m^3) and road drivers (2.7 ug/m^3), and exposures significantly above background highway concentrations in mechanics (10.7 ug/m^3). Mechanics (working in the shop) were found to have the highest exposures to elemental carbon, organic carbon, nitrogen dioxide, nitric oxide, and respirable dust. Area concentrations of airborne respirable particulate indicated the same relative ranking of jobs suggested by exposures to elemental carbon (dock workers lowest, followed in order by local drivers, road drivers, and mechanics). Exposures to NO, NO_2, and respirable particulate were far below OSHA PELs or NIOSH RELs for these contaminants.

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 Advance Transportation Company break bulk terminal in Milwaukee, Wisconsin during the period November 28 to December 1, 1988. During the survey, 68 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 35 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 and elemental and organic carbon content of total airborne particulate. 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

The progenitor of Advance Transportation Company was founded in 1923 in Milwaukee as a family hauling business. In 1928, The founders incorporated as Lindner Bros. Trucking, Inc., and in 1930, the company purchased another company, Advance Transportation Company. The resulting company, Advance Transportation Company, has been expanding since that time and currently has over 37 truck terminals and relay stations located in 11 states, employing over 950 people and hauling in excess of 25 million pounds of freight per day nationwide. The corporate offices of Advance Transportation Company are located at this terminal in Milwaukee, Wisconsin.

Advance Transportation's Milwaukee terminal is a medium size break bulk terminal consisting of line-haul (long distance) and city (local area) freight transport, as well as dock and tractor/trailer repair shop operations. The site currently includes the company's corporate and terminal offices (totalling 30,000 square feet) and a truck/driver dispatching area (all located adjacent to the dock), a 102-door dock, and one of the company's largest tractor/trailer maintenance facilities. The facility, opened in 1973, is situated on a 30 acre site on South Sixth Street (near the airport) in Milwaukee, and employs nearly 300 people. The truck yard surrounding the dock and offices is asphalt paved.

Dock Operations

The Milwaukee 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 63,000 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.

The corporate and 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 102 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 three shifts.

The terminal currently owns 18 Mitsubishi Co. tow-motor trucks. However, only five or six of these are operated on a given shift. All of the towmotors are propane-engine powered.

Repair Shop Operations

The repair shop totals approximately 13,000 square feet, and is in a separate building from the main terminal. The repair shop at this site consists of a tractor shop, a tow-motor (forklift) shop, a trailer shop, a lubrication and wash rack, a dynamometer, a parts room, and shop offices. All of the shops are contiguous within the same building, and are not isolated from one another. The tractor shop has one large overhead door (16' x 18') at one end, a center driving lane, and ten repair bays 18-20 feet long located at angles to the center lane. The tow-motor repair shop consists of a single room adjacent to one end of the tractor shop. A dynamometer room is located at the opposite end of the tractor shop (near the overhead door). The trailer shop consisted of four drive-in bays in which service, welding and mechanical work were performed on trailers. The lubrication and wash rack is located adjacent to the trailer shop lanes and at the opposite end from the tractor/forklift repair shops.

Minor and medium level repairs are done in the repair shops, and routine safety checks and services are done in the lubrication/wash rack area. City tractors are serviced every 2 months or 6000 miles, highway tractors every month or 12,500 miles, and trailers every 3 months. The mechanics in charge of these lanes run through a checklist of service/safety items (oil, brakes, grease, tires, lights, wipers, etc.) to determine the operating condition of the vehicle.

The tractor shop does most tuneups, and mechanical, brake, tire, wheel, engine, transmission, and electrical repairs. During the survey, the large bay door was kept closed due to the cold (approximately 40-45 degree F. daytime highs) ambient temperatures. Local exhaust hoods were available at each repair bay. These were attached to the trucks' exhaust stacks via flexible tubing if the truck engine remained running while in the shop. In addition, the building was fitted with a general room air ventilation system, including room exhaust and tempered makeup air, which was left running constantly.

The dynamometer room (used for engine checks and other repairs in which the engine must remain running for long periods) had two wall-mounted exhaust fans located on the outside wall approximately ten feet above the ground. These fans were probably not efficient in removing exhaust from the dynamometer room, since the intakes were located approximately 50 feet from the corner where the tractor exhaust stacks were typically located. However, their effectiveness could not be judged since the room was not used during the survey.

Non-asbestos composition brake linings have been exclusively used since about six to eight years ago, and non-asbestos clutches since about five years ago. 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

Approximately 95% of Advance Transportation Company's road and city tractors are manufactured by the Ford Motor Company. The road tractors are Ford LT 9000 models powered by Caterpillar 3406 diesel engines. A small number of Mack Co. tractors are still in use in the road fleet company wide but are being phased out. Almost 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. Only a small number (about 32 corporate wide) of Ford CL 9000 cabover tractors, some as old as

1984 model year, are used in the road fleet by Advance Transportation. All of the road tractors are currently fitted with air conditioning.

The city tractors are typically Ford LN 8000 conventional design models powered by Caterpillar 3208 or 3208T (turbo) diesel engines (until 1988, when new tractors were ordered with Ford in-line engines). A few International Harvester Company tractors (21 corporate wide) powered by Detroit Diesel Co. DT466 diesel engines, and about 8-10 Ford CL 9000 tractors (as old as 1978 model year) are used in the city fleet. City tractors do not (and have never) had air conditioning installed.

All road and city tractors used by Advance Transportation Company are configured with vertical (stack) exhaust systems located on the right hand side (opposite the driver) of the tractor. Company personnel indicated that the tractors currently used are typically 1984 to 1988 models. 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 25 years ago, and was probably complete by the early 1960s.

The tractor fleet runs mostly (90%) on Amoco grade #2 diesel fuel in the summer. In the winter, a blend of 75% grade #2 and 25% grade #1 fuel is used. Most of the refueling is done at the terminal and is bought in bulk for this purpose. A few of the older cabover tractors (road and city) are equipped with over-cab air deflectors, but most of the newer Ford tractors are not.

WORKFORCE DESCRIPTION

Approximately 299 persons were, as of the date of the survey, employed at the terminal. These included about 53 dock employees (including yard jockeys), 68 road (line) drivers, and 54 local (city) drivers. The terminal also employed 37 office/clerical employees, 2 professional accountants (C.P.A.s), 6 technicians (data processing), 5 persons in sales, and 38 management personnel. The repair shop employed 25 mechanics, 3 lubricators, 1 fueler, 5 tiremen, and 1 washer. The terminal also employed one facilities maintenance person. With the exception of the clerical employees and secretaries, and three managers, all were male.

The dock and repair shop operate on three eight-hour shifts, 24 hours per day. Line drivers originating at the Milwaukee terminal are "on-call", but most start their shift in the late afternoon or early evening, which typically lasts 10-12 hours. The terminal has no "sleeper" runs (in which the driver returns the next day), but is a single relay, line haul operation, 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 Advance Transportation Company has a well developed safety program, with a director of safety and personnel located at the terminal, as well as a safety committee which meets at least once per month. The committee is composed of employees representing all major areas (dock, road and city drivers, and maintenance) at the terminal. The program includes extensive new-employee and periodic training programs in safety and hazardous materials.

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 a nearby clinic. For road and city drivers only, 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. The examination also includes audiometry, but no spirometry or X-rays. Appendix A is a blank form used for the examination.

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. NIOSH, in its Current Intelligence Bulletin No. 50, has indicated that "as prudent public health policy, employers should reduce exposure (to whole diesel exhaust) to the lowest feasible limits" (1).

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 the second shift, and an equivalent number of personal samples were obtained from mechanics and local drivers during the day shift. The sampling was conducted for three days (six shifts) during November 28 to December 1, 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, and 3) elemental and organic carbon content in total (not size selected) airborne particulate. Sampling for PAHs and nitro-PAHs (see Table II) was considered, but concentrations of diesel exhaust were subjectively determined to be too low (by observation of deposited carbon on filters obtained on the first day) during this survey to make such sampling feasible.

Two area samples of each of the three types indicated above were obtained on each shift, one in each of the two areas sampled; i.e., in the tractor shop and in city tractor cabs during the day shift, and on the dock 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) at a flow rate of 4 Lpm instead of 2 Lpm. "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.

Although sampling for PAHs and N-PAHs was not conducted due to the apparent low diesel aerosol concentrations, the following is a description of the method which was used in surveys at other terminals. Concentrations of polynuclear aromatic hydrocarbons (PAHs) and nitro-substituted PAHs (N-PAHs) are 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 are collected on the PTFE membrane filters, and volatile/semivolatile PAHs are collected by the washed XAD-2 resin.

During sampling, air is 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 are wrapped with aluminum foil to prevent ultraviolet (UV) degradation of collected PAHs. After sampling, the filter is transferred to a glass scintillation vial, and both the vial and the recapped Orbo-43 tube are again wrapped in aluminum foil. Samples are kept frozen until analysis by the laboratory. In the laboratory, both filters and resin are desorbed with acetonitrile. Fourteen PAHs and two N-PAHs (2-nitrofluorene and 1-nitropyrene) can be 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, 4, and 5 are similar charts illustrating exposures to nitrogen dioxide, nitric oxide (NO), 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 NO concentrations by job or area. Table VII is a statistical summary of respirable dust concentrations in four areas. Tables 1- 5 in Appendix B contain the individual personal, eight-hour, time weighted average exposures to elemental and organic carbon, NO_2, NO, and respirable dust. No tables of PAH or nitro-PAH concentrations are included in this report because sampling was not conducted for these compounds during this survey. 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 1.3 ug/m^3 in dock workers to 10.7 ug/m^3 in mechanics. The intermediate job means were (from low to high - refer to Figure 1): local drivers (2.4 ug/m^3), and road drivers (2.7 ug/m^3). Area concentrations in four areas averaged 1.2 ug/m^3 on the dock, 2.5 ug/m^3 in road tractor cabs, 8.5 ug/m^3 in local cabs, and 9.1 ug/m^3 in the tractor shop. The somewhat elevated mean value in local cabs (8.5 ug/m^3) can be explained by the fact that one area sample (Sample No. ATC.65 in Table 1, 70.3 ug/m^3) was obtained in the cab of an older (ca 1978) Ford cabover tractor, which was known to emit higher levels of particulate.

By contrast, concentrations measured on a major interstate freeway within Milwaukee averaged 1.28 ug/m^3 (range: 0.86 to 1.98 ug/m^3 in three samples), and in a residential area (at least one mile from the nearest highway or freeway) averaged 1.28 ug/m^3 (range: 0.52 to 2.52 ug/m^3 in three samples).

Inspection of Figure 1 indicates that mean exposures to elemental carbon in three jobs, dock workers, local drivers, and road drivers were either essentially indistinguishable from highway background concentrations or only slightly higher. However, in mechanics, exposures 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 mechanics, suggesting that only mechanics' true job means 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 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 samples. This suggests that essentially all diesel exhaust particulate is being collected by the dichotomous sampling cassette, and that the great majority of these particles are in fact below 1 micrometer in aerodynamic diameter. Mean concentrations of elemental carbon in these samples ranged from 1.7 ug/m^3 on the dock to 8.34 ug/m^3 in the tractor 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 17 ug/m^3 in road drivers to a high of 65.8 ug/m^3 in mechanics. Other job means (Table IV and Figure 2) were intermediate to these. Geometric mean area concentrations of organic carbon ranged from 5.48 ug/m^3 on the dock to 31.2 ug/m^3 in the tractor shop area.

Residential area concentrations of submicrometer organic carbon averaged 0.59 ug/m^3, and highway ambient area concentrations averaged 1.27 ug/m^3. The 95% LCL of personal samples from all four jobs were higher than the 95% UCL for the highway samples (5.25 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. For example, only propane powered tow-motors were operated on the dock, indicating that dock workers had no nearby source of diesel exposure (except perhaps the switching truck or other tractors operating in the yard outside the dock). Dock workers' exposures to elemental carbon were essentially at background level, while their exposures to organic carbon were substantially higher.

Oxides of Nitrogen

Nitrogen dioxide (NO_2) concentrations determined in personal samples from 4 jobs (Figure 3 and Table V) ranged from 0.02 ppm (road drivers) to 0.21 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 0.012 ppm in road drivers to 0.74 ppm in mechanics. These exposures are again far below applicable OSHA PELs or NIOSH RELs (Table I).

Respirable Dust

Figure 5 and Table VII summarize concentrations of respirable dust obtained in specific areas of the repair shop, dock, and in local and road truck tractors. Respirable dust concentrations in the dock area averaged 19.6 ug/m^3, 50.1 ug/m^3 in local cabs, 51.5 ug/m^3 in road cabs, and 77.6 ug/m^3 in the tractor shop area.

CONCLUSIONS

1. Based on measurements of personal, breathing zone concentrations of elemental carbon at this terminal, it appears that only mechanics' exposures to diesel aerosol were elevated significantly above background highway concentrations found in the Milwaukee area. The somewhat higher exposures of mechanics (relative to other jobs) were very likely due to the more enclosed environment in which they were working. However, this conclusion is not a rigorous one, since the small sample sizes generated necessarily wide confidence limits. 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, approximately equal to the geometric mean ambient residential concentrations. Highway concentrations were in general somewhat lower than in other cities in which similar measurements have been made, and residential background concentrations were about the same. 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, degreasing solvent vapors, or tobacco smoke, in the samples. In fact, the generally very low concentrations of submicrometer elemental

carbon in most samples suggest that very little if any diesel aerosol was present in most jobs or areas, except in mechanics and in the shop.

4. The relative rankings of jobs suggested by personal exposures to submicrometer elemental carbon and area concentrations of respirable dust were not conspicuously different. Mean exposures to both contaminants suggested that the lowest exposures were in dock workers, followed in order by local drivers, road drivers, and 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. 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 cabover) 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 or propane powered vehicles for diesel powered vehicles.

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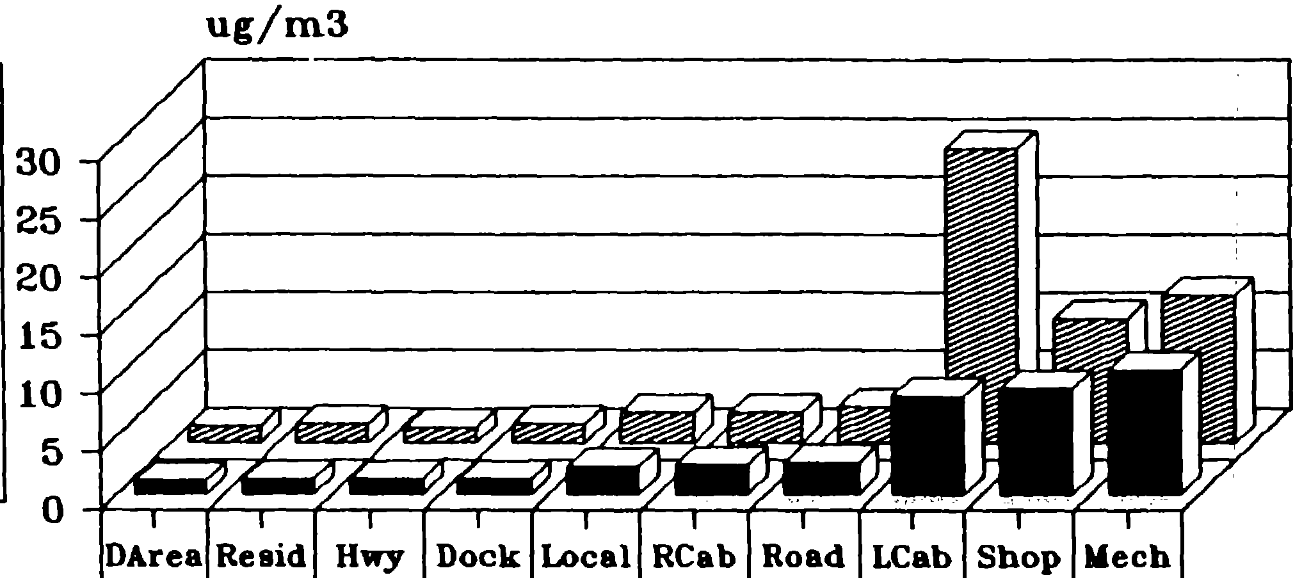
Figure 1. Elemental Carbon Exposure
Advance Transportation Company



DArea = Dock Area
Resid = Residential
Hwy = Highway
Dock = Dock Worker
Local = Local Driver
RCab = Road Cab
Road = Road Driver
LCab = Local Cab
Shop = Shop Area
Mech = Mechanic

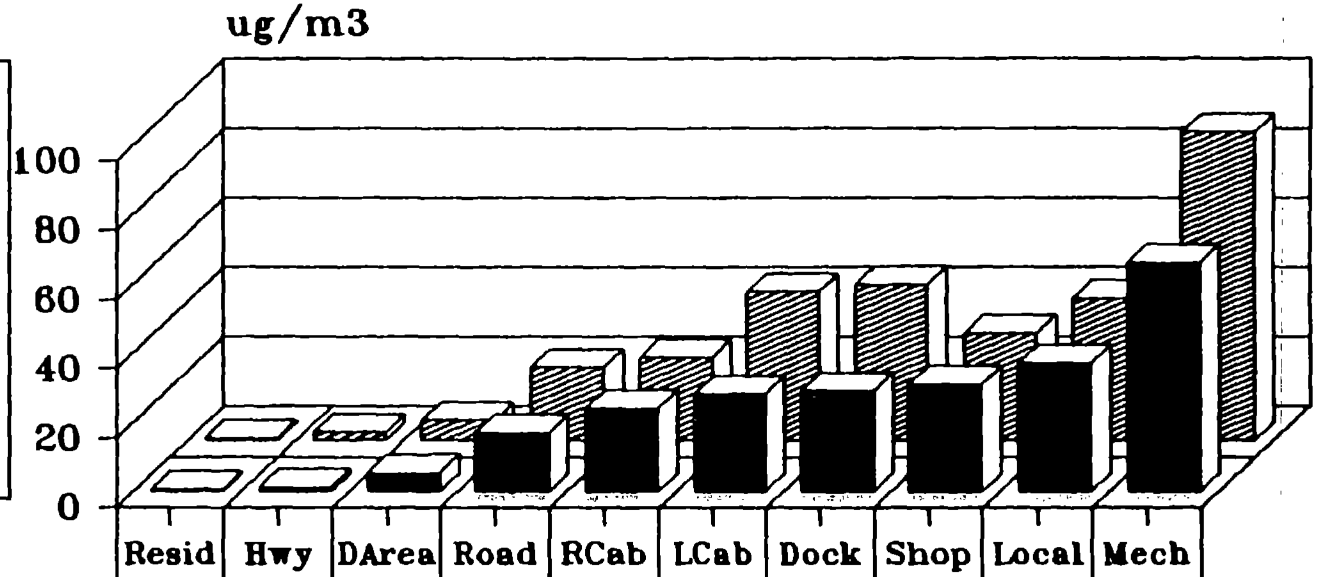
	DArea	Resid	Hwy	Dock	Local	RCab	Road	LCab	Shop	Mech
Arithmetic Mean	1.4	1.6	1.3	1.6	2.6	2.6	3.1	25.4	10.7	12.7
Geometric Mean	1.2	1.3	1.3	1.3	2.4	2.5	2.7	8.5	9.1	10.7

Job/Area

Geometric Mean   Arithmetic Mean

November 1988

Figure 2. Organic Carbon Exposure
Advance Transportation Company



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Road = Road Driver
LCab = Local Cab
Shop = Shop Area
Mech = Mechanic

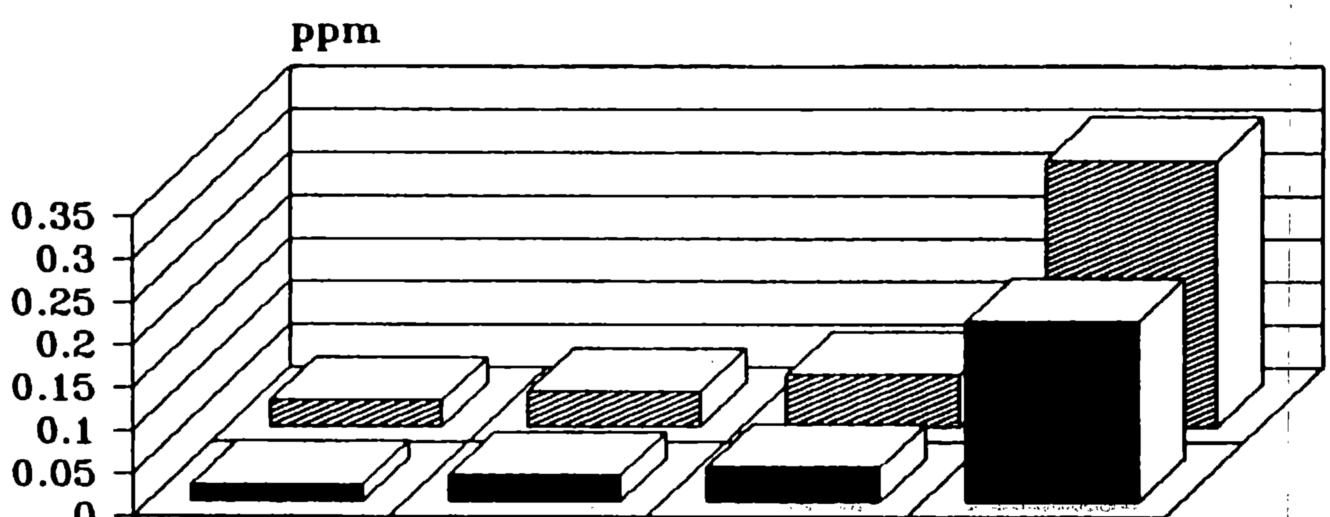
	Resid	Hwy	DArea	Road	RCab	LCab	Dock	Shop	Local	Mech
Arithmetic Mean	0.6	2.3	5.8	21	24	43	45	31	41	89
Geometric Mean	0.6	1.3	5.5	17	24	28	29	31	37	66

Job/Area

Geometric Mean   Arithmetic Mean

November 1988

Figure 3. Nitrogen Dioxide Exposures Advance Transportation Co.



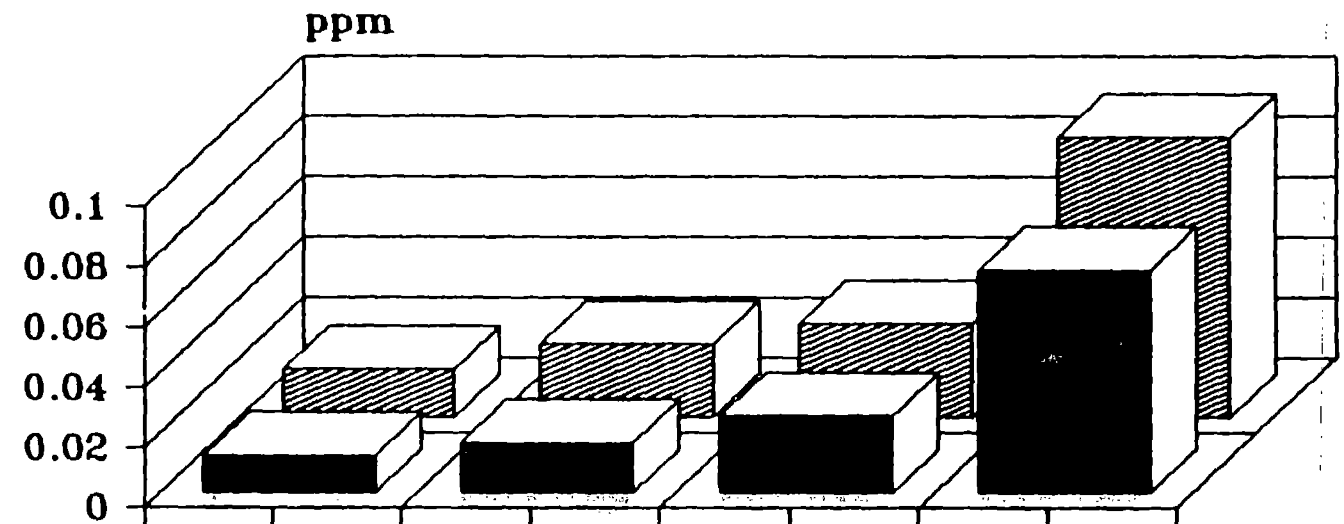
	Road Driver	Dock Worker	Local Driver	Mechanic
Arithmetic Mean	0.03	0.04	0.06	0.31
Geometric Mean	0.02	0.03	0.04	0.21

Job/Area

Geometric Mean   Arithmetic Mean

November 1988

Figure 4. Nitric Oxide Exposures
Advance Transportation Co.



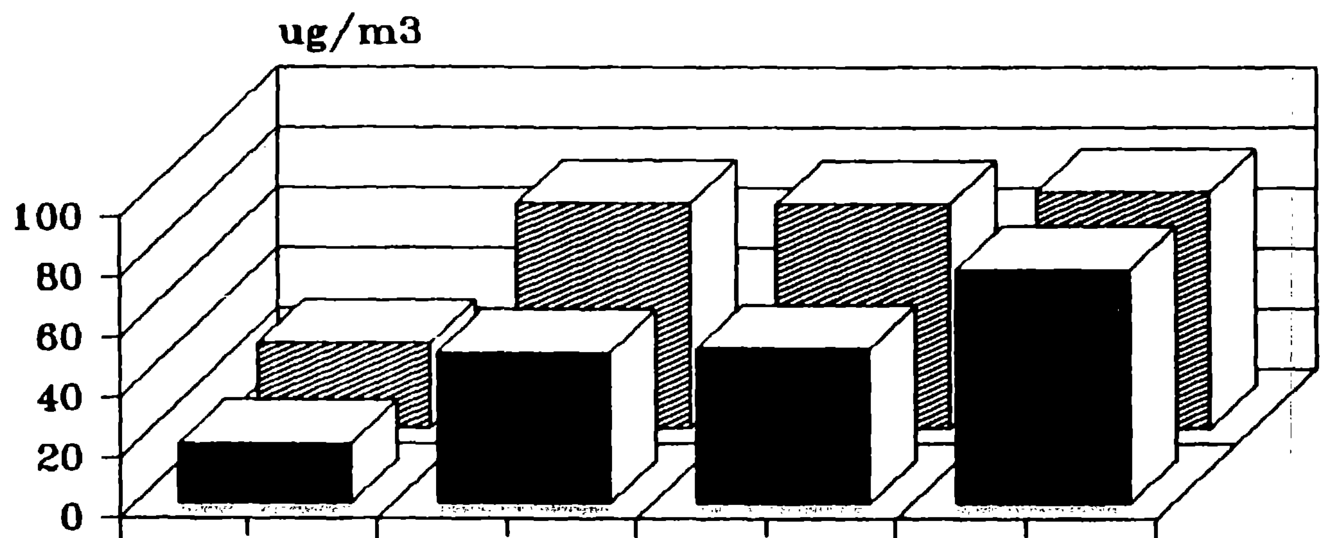
	Road Driver	Local Driver	Dock Worker	Mechanic
Arithmetic Mean	0.016	0.024	0.031	0.093
Geometric Mean	0.012	0.016	0.025	0.074

Job/Area

Geometric Mean   Arithmetic Mean

November 1988

Figure 5. Respirable Dust Exposures Advance Transportation Co.



	Dock Area	Local Cab	Road Cab	Shop Area
Arithmetic Mean	28.1	74.7	74.4	78.4
Geometric Mean	19.6	50.1	51.5	77.6

Job/Area

Geometric Mean   Arithmetic Mean

November 1988

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

		MSHA PELs*		
Component	OSHA PEL	Underground coal mines	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 Advance Transportation Co.; November 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
Advance Transportation Company
(ug/m3)

Job or Area	N	Min	Max	Arithmetic Mean	Error	Geometric Mean	Geometric Std. Dev.	95% Confidence Limit Lower	95% Confidence Limit Upper
Dock Area	3	0.57	1.93	1.40	0.42	1.23	1.95	0.23	6.48
Residential	5	0.52	2.52	1.56	0.41	1.28	2.12	0.50	3.27
Highway	5	0.86	1.98	1.35	0.21	1.28	1.41	0.84	1.96
Dock	12	0.53	4.97	1.61	0.35	1.30	1.97	0.85	2.00
Local	10	1.20	5.15	2.60	0.39	2.35	1.61	1.67	3.30
Road Cab	3	2.03	3.10	2.55	0.31	2.51	1.24	1.48	4.25
Road	12	1.10	8.17	3.08	0.56	2.66	1.72	1.88	3.76
Local Cab	3	2.81	70.3	25.4	22.5	8.50	6.24	0.09	804
Shop Area	3	4.32	18.4	10.7	4.11	9.07	2.06	1.50	54.8
Mechanic	12	4.90	35.0	12.7	2.47	10.7	1.78	7.44	15.5
Elemental Carbon in Total Airborne Particulate:									
Dock Area (Total)	3	1.33	2.28	1.74	0.28	1.70	1.31	0.86	3.35
Road Cab (Total)	3	1.69	2.47	1.98	0.25	1.95	1.23	1.18	3.25
Local Cab (Total)	3	1.18	34.4	12.9	10.8	5.00	5.68	0.07	374
Shop Area (Total)	3	5.07	16.0	9.41	3.36	8.34	1.81	1.92	36.2

Table IV. Organic Carbon Summary Statistics
By Job or Specific Location
Advance Transportation Company
(ug/m3)

Job or Area	N	Min	Max	Arithmetic Mean	Error	Geometric Mean	Std. Dev.	95% Confidence Limit Lower	Upper
Residential	5	0.52	0.7	0.6	0.03	0.59	1.13	0.51	0.7
Highway	5	0.52	8.10	2.34	1.46	1.27	3.15	0.30	5.25
Dock Area	3	3.45	8.00	5.80	1.31	5.48	1.53	1.90	15.8
Road	12	1.41	46.4	21.4	3.45	17.0	2.41	9.73	29.7
Road Cab	3	19.8	30.9	24.2	3.41	23.8	1.26	13.3	42.5
Local Cab	3	11.3	97.9	42.7	27.7	27.5	3.09	1.67	453
Dock	12	11.4	187	45.0	15.1	29.0	2.47	16.3	51.6
Shop Area	3	30.0	33.1	31.2	0.95	31.2	1.05	27.4	35.5
Local	10	18.6	69.0	41.0	5.83	37.4	1.58	27.0	51.8
Mechanic	12	31.4	298	88.7	24.2	65.8	2.12	40.8	106
Organic Carbon in Total Airborne Particulate:									
Dock Area (Total)	3	18.3	31.7	24.6	3.89	24.0	1.32	12.1	47.6
Road Cab (Total)	3	28.3	49.5	40.3	6.29	39.3	1.34	19.0	81.1
Local Cab (Total)	3	13.5	122	58.3	32.9	40.1	3.01	2.60	618
Shop Area (Total)	3	55.6	72.8	66.1	5.34	65.7	1.16	45.7	94.4

Table V. Nitrogen Dioxide Summary Statistics
By Job or Specific Location
Advance Transportation Company
(ppm)

Job or Area	N	Min	Max	Arithmetic Mean	Arithmetic S.E.	Geometric Mean	Geometric Std. Dev.	95% Confidence Limit Lower	95% Confidence Limit Upper
Road	9	0.01	0.08	0.02	0.01	**0.02**	1.87	0.01	0.03
Dock	9	0.02	0.12	0.04	0.01	**0.03**	2.09	0.02	0.05
Local	9	0.01	0.11	0.06	0.01	**0.04**	2.66	0.02	0.09
Mechanic	8	0.02	0.47	0.31	0.06	**0.21**	3.42	0.08	0.59

Table VI. Nitric Oxide Summary Statistics
By Job or Specific Location
Advance Transportation Co.
(ppm)

Job or Area	N	Min	Max	Arithmetic Mean	Arithmetic Error	Geometric Mean	Geometric Std. Dev.	95% Confidence Limit Lower	95% Confidence Limit Upper
Road	9	0.01	0.05	0.02	0.00	**0.01**	2.07	0.01	0.02
Local	9	0.00	0.08	0.02	0.01	**0.02**	2.69	0.01	0.04
Dock	9	0.01	0.09	0.03	0.01	**0.03**	1.93	0.02	0.04
Mechanic	8	0.04	0.28	0.09	0.03	**0.07**	1.94	0.04	0.13

Table VII. Respirable Dust Summary Statistics
By Job or Specific Location
Advance Transportation Company
(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
Dock Area	3	6.70	58.4	28.1	15.6	19.6	2.95	1.33	289
Local Cab	3	24.3	169	74.7	47.3	50.1	2.89	3.60	697
Road Cab	3	27.0	165	74.4	45.5	51.5	2.75	4.17	637
Shop Area	3	65.1	91.0	78.4	7.47	77.6	1.18	51.1	118

Appendix A
Medical Exam Form
Advance Transportation Company
Milwaukee, WI

Name: ______________________________

Address: ______________________________

Social Security No.: ______________ Date of Birth: ______________ Age: ______

Height ______ Ft. ______ In. Weight ______ lbs.

☐ New Certification

☐ Recertification

HEALTH HISTORY

Yes	No		Yes	No	
☐	☐	Head or spinal injuries.	☐	☐	Nervous stomach.
☐	☐	Seizures, fits, convulsions, or fainting.	☐	☐	Rheumatic fever.
☐	☐	Extensive confinement by illness or injury.	☐	☐	Asthma.
☐	☐	Cardiovascular disease.	☐	☐	Kidney disease.
☐	☐	Tuberculosis.	☐	☐	Muscular disease.
☐	☐	Syphilis.	☐	☐	Suffering from any other disease.
☐	☐	Gonorrhea.	☐	☐	Permanent defect from illness, disease or injury.
☐	☐	Diabetes.	☐	☐	Psychiatric disorder.
☐	☐	Gastrointestinal ulcer.	☐	☐	Any other nervous disorder.

If answer to any of the above is yes, explain: ______________________________

PHYSICAL EXAMINATION

GENERAL APPEARANCE AND DEVELOPMENT: Good: ______ Fair: ______ Poor: ______

VISION: For distance: Right 20/______ Left 20/______ Both 20/______ ☐ Without corrective lenses ☐ With corrective lenses if worn

Evidence of disease of injury: Right: ______ Left: ______ Color Test: ______

Horizontal field of vision: Right ______ Left ______

HEARING: Right ear ______ Left ear ______ Disease or injury ______

AUDIOMETRIC TEST (complete only if audiometer is used to test hearing) decibel loss at 500 Hz ______,

at 1,000 Hz ______, at 2,000 Hz ______

THROAT ______

THORAX: Heart ______ If organic disease is present, is it fully compensated? ______

Blood pressure: Systolic ______ Diastolic ______

Pulse: Before exercise ______ Immediately after excercise ______ Lungs ______

ABDOMEN: Scars ______ Abnormal masses ______ Tenderness ______

Hernia: Yes ______ No ______ If so, where? ______ Is truss worn? ______

GASTROINTESTINAL: Ulceration or other disease: Yes ______ No ______

GENITO-URINARY: Scars ______ Urethral discharge ______

REFLEXES: Romberg ______ Pupillary ______ Light R ______ L ______

Accommodation Right ______ Left ______

Knee Jerks: Right: Normal ______ Increased ______ Absent ______

Left: Normal ______ Increased ______ Absent ______

Remarks: ______

EXTREMITIES: Upper ______ Lower ______ Spine ______

LABORATORY AND OTHER SPECIAL FINDINGS: Urine: Spec. Gr. ______ Alb. ______ Sugar ______

Other laboratory data (serology, etc) ______

Radiological data ______ Electrocardiograph ______

GENERAL COMMENTS ______

(Date of examination) (Address of examining doctor) (Name of examining doctor) (Print)

☐ **CHECK HERE IF NOT QUALIFIED**

(Signature of examining doctor)

NOTE: This section to be completed only when visual test is conducted by a licensed optometrist or ophthalmologist.

(Date of examination) (Address of examiner) (Name of examiner) (Print)

(Signature of examiner)

MEDICAL EXAMINER'S CERTIFICATE

I certify that I have examined ______________ in accordance with the Federal Motor Carrier Safety Regulations
(Driver's name) (Print)
(49 CFR 391.41-391.49) and with knowledge of his duties, I find him qualified under the regulations.

☐ Qualified only when wearing corrective lenses.
☐ Qualified only when wearing a hearing aid.

A completed examination form for this person is on file in my office at ______________
(Address)

(Date of examination) (Name of examining doctor) (Print) (Signature of examining doctor)

(Address of driver) (Signature of driver)

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(REV. 8/87)

Appendix B
Tables 1-5
Individual Sample Results
Advance Transportation Company
Milwaukee, WI

Table 1. Concentrations of Elemental Carbon
Advance Transportation Company
November 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
11-28	ATC.4	Dock	15	39	23	23	4.0	<2.0	464	1856	<1.08
11-28	ATC.3	Dock	15	41	23	24	4.0	<2.0	463	1852	<1.08
11-28	ATC.2	Dock	15	34	23	22	4.0	<2.0	468	1872	<1.08
11-28	ATC.1	Dock	15	31	23	18	4.0	2.59	467	1868	1.39
11-29	ATC.30	Dock	15	42	23	17	4.0	9.04	455	1820	4.97
11-29	ATC.29	Dock	15	43	21	21	4.0	1.56	338	1352	1.16
11-29	ATC.28	Dock	15	36	23	22	4.0	3.06	466	1864	1.64
11-29	ATC.27	Dock	15	40	23	25	4.0	3.53	465	1860	1.90
11-30	ATC.44	Dock	16	3	23	49	4.0	3.71	466	1864	1.99
11-30	ATC.45	Dock	16	4	23	21	4.0	2.87	437	1748	1.64
11-30	ATC.43	Dock	15	46	23	15	4.0	1.56	449	1796	0.87
11-30	ATC.46	Dock	16	5	23	40	4.0	3.99	455	1820	2.19
11-28	ATC.5	Dock Area	16	13	23	32	4.0	<2.0	439	1756	<1.14
11-29	ATC.26	Dock Area	15	55	23	29	4.0	3.06	454	1816	1.68
11-30	ATC.47	Dock Area	15	33	23	9	4.0	3.53	456	1824	1.93
11-28	ATTC.1	Dock Area (Total)	16	14	22	41	4.0	3.53	387	1548	2.28
11-29	ATTC.6	Dock Area (Total)	15	57	23	30	4.0	2.40	453	1812	1.33
11-30	ATTC.9	Dock Area (Total)	15	37	23	13	4.0	2.96	456	1824	1.63
11-29	ATC.58	Highway	16	30	0	30	4.0	3.15	480	1920	1.64
11-29	ATC.22A	Highway	8	10	15	46	4.0	3.62	456	1824	1.98
11-30	ATC.68	Highway	21	20	23	46	4.0	0.72	146	584	1.23
11-30	ATC.42	Highway	7	49	12	39	4.0	1.00	290	1160	0.86
12-1	ATC.70	Highway	7	19	15	19	4.0	1.94	480	1920	1.01
11-29	ATC.17	Local	8	24	16	24	4.0	6.89	480	1920	3.59
11-29	ATC.18	Local	8	22	16	22	4.0	6.80	480	1920	3.54
11-29	ATC.20	Local	8	20	16	20	4.0	3.25	480	1920	1.69
11-29	ATC.19	Local	8	20	16	20	4.0	9.88	480	1920	5.15
11-30	ATC.36	Local	8	5	16	5	4.0	4.83	480	1920	2.52
11-30	ATC.38	Local	8	8	16	8	4.0	5.30	480	1920	2.76
11-30	ATC.39	Local	8	10	16	10	4.0	2.87	480	1920	1.50
11-30	ATC.37	Local	8	6	16	6	4.0	2.31	480	1920	1.20
12-1	ATC.63	Local	9	9	17	9	4.0	5.11	480	1920	2.66
12-1	ATC.66	Local	7	58	15	58	4.0	2.68	480	1920	1.40
11-29	ATC.11	Local Cab	8	46	16	46	4.0	5.96	480	1920	3.10
11-30	ATC.40	Local Cab	8	30	16	30	4.0	5.40	480	1920	2.81
12-1	ATC.65	Local Cab	9	28	17	28	4.0	135.05	480	1920	70.3
11-29	ATTC.3	Local Cab (Total)	8	46	19	58	4.0	8.29	672	2688	3.09

Table 1. Concentrations of Elemental Carbon (Cont'd)
Advance Transportation Company
November 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
11-30	ATTC.8	Local Cab (Total)	8	30	18	38	4.0	2.87	608	2432	**1.18**
12-1	ATTC.11	Local Cab (Total)	9	28	18	28	4.0	74.20	540	2160	**34.4**
11-29	ATC.16	Mechanic	7	7	15	7	4.0	13.72	480	1920	**7.14**
11-29	ATC.13	Mechanic	7	12	15	12	4.0	9.41	480	1920	**4.90**
11-29	ATC.15	Mechanic	7	10	15	10	4.0	13.15	480	1920	**6.85**
11-29	ATC.14	Mechanic	7	10	15	10	4.0	32.60	480	1920	**17.0**
11-30	ATC.34	Mechanic	7	8	15	2	4.0	36.34	474	1896	**19.2**
11-30	ATC.31	Mechanic	7	4	15	4	4.0	34.19	480	1920	**17.8**
11-30	ATC.32	Mechanic	7	5	15	5	4.0	16.80	480	1920	**8.75**
11-30	ATC.33	Mechanic	7	6	11	3	4.0	12.50	237	948	**13.2**
11-31	ATC.53	Mechanic	7	5	15	5	4.0	67.19	480	1920	**35.0**
11-31	ATC.54	Mechanic	7	3	15	3	4.0	13.62	480	1920	**7.09**
11-31	ATC.59	Mechanic	7	5	15	5	4.0	15.12	480	1920	**7.87**
11-31	ATC.60	Mechanic	7	4	15	4	4.0	14.28	480	1920	**7.44**
11-29	ATC.57	Residential	16	40	23	35	4.0	3.34	415	1660	**2.01**
11-29	ATC.21A	Residential	6	43	14	43	4.0	4.83	480	1920	**2.52**
11-30	ATC.41	Residential	7	55	13	57	4.0	3.11	362	1448	**2.15**
11-30	ATC.67	Residential	17	15	0	1	4.0	<2.0	406	1624	**<1.23**
12-1	ATC.69	Residential	7	27	15	27	4.0	1.00	480	1920	**0.52**
11-28	ATC.7	Road	18	37	22	24	4.0	<2.0	227	908	**<2.20**
11-28	ATC.8	Road	20	2	4	2	4.0	5.21	480	1920	**2.71**
11-28	ATC.9	Road	20	10	4	10	4.0	6.14	480	1920	**3.20**
11-28	ATC.10	Road	20	14	4	5	4.0	15.40	471	1884	**8.17**
11-29	ATC.24	Road	20	3	4	3	4.0	4.09	480	1920	**2.13**
11-29	ATC.25	Road	20	7	4	7	4.0	2.78	480	1920	**1.45**
11-29	ATC.23	Road	19	58	3	58	4.0	4.74	480	1920	**2.47**
11-29	ATC.22	Road	19	22	3	22	4.0	8.48	480	1920	**4.42**
11-30	ATC.48	Road	19	58	3	58	4.0	9.23	480	1920	**4.81**
11-30	ATC.49	Road	20	7	4	7	4.0	3.62	480	1920	**1.88**
11-30	ATC.50	Road	18	35	2	35	4.0	4.46	480	1920	**2.32**
11-30	ATC.51	Road	19	59	3	59	4.0	4.37	480	1920	**2.27**
11-28	ATC.6	Road Cab	18	38	2	38	4.0	3.90	480	1920	**2.03**
11-29	ATC.21	Road Cab	19	30	3	30	4.0	4.83	480	1920	**2.52**
11-30	ATC.52	Road Cab	18	38	2	38	4.0	5.96	480	1920	**3.10**
11-28	ATTC.2	Road Cab (Total)	18	38	2	38	4.0	3.25	480	1920	**1.69**
11-29	ATTC.5	Road Cab (Total)	19	30	3	30	4.0	3.43	480	1920	**1.79**
11-30	ATTC.10	Road Cab (Total)	18	40	2	40	4.0	4.74	480	1920	**2.47**

Table 1. Concentrations of Elemental Carbon (Cont'd)
Advance Transportation Company
November 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
11-29	ATC.12	Shop Area	7	0	15	0	4.0	8.29	480	1920	**4.32**
11-30	ATC35	Shop Area	6	55	15	2	4.0	35.78	487	1948	**18.4**
11-31	ATC.61	Shop Area	6	52	14	56	4.0	18.20	484	1936	**9.40**
11-29	ATTC.4	Shop Area (Total)	7	0	15	17	4.0	10.07	497	1988	**5.07**
11-30	ATTC.7	Shop Area (Total)	6	55	14	59	4.0	31.01	484	1936	**16.0**
11-31	ATTC.12	Shop Area (Total)	6	52	14	55	4.0	13.81	483	1932	**7.15**

Table 2. Concentrations of Organic Carbon
Advance Transportation Company
November 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
11-28	ATC.4	Dock	15	39	23	23	4.0	29.9	464	1856	**16.1**
11-28	ATC.3	Dock	15	41	23	24	4.0	22.2	463	1852	**12.0**
11-28	ATC.2	Dock	15	34	23	22	4.0	21.4	468	1872	**11.4**
11-28	ATC.1	Dock	15	31	23	18	4.0	23.4	467	1868	**12.5**
11-29	ATC.30	Dock	15	42	23	17	4.0	340	455	1820	**187**
11-29	ATC.29	Dock	15	43	21	21	4.0	43.2	338	1352	**31.9**
11-29	ATC.28	Dock	15	36	23	22	4.0	38.8	466	1864	**20.8**
11-29	ATC.27	Dock	15	40	23	25	4.0	29.7	465	1860	**16.0**
11-30	ATC.44	Dock	16	3	23	49	4.0	99.5	466	1864	**53.4**
11-30	ATC.45	Dock	16	4	23	21	4.0	84.6	437	1748	**48.4**
11-30	ATC.43	Dock	15	46	23	15	4.0	42.0	449	1796	**23.4**
11-30	ATC.46	Dock	16	5	23	40	4.0	195	455	1820	**107**
11-28	ATC.5	Dock Area	16	13	23	32	4.0	10.5	439	1756	**6.0**
11-29	ATC.26	Dock Area	15	55	23	29	4.0	6.3	454	1816	**3.4**
11-30	ATC.47	Dock Area	15	33	23	9	4.0	14.6	456	1824	**8.0**
11-28	ATTC.1	Dock Area (Total)	16	14	22	41	4.0	49.1	387	1548	**31.7**
11-29	ATTC.6	Dock Area (Total)	15	57	23	30	4.0	43.3	453	1812	**23.9**
11-30	ATTC.9	Dock Area (Total)	15	37	23	13	4.0	33.4	456	1824	**18.3**
11-29	ATC.58	Highway	16	30	0	30	4.0	<2.0	480	1920	**<1.0**
11-29	ATC.22A	Highway	8	10	15	46	4.0	14.8	456	1824	**8.1**
11-30	ATC.68	Highway	21	20	23	46	4.0	<2.0	146	584	**<3.4**
11-30	ATC.42	Highway	7	49	12	39	4.0	<2.0	290	1160	**<1.7**
12-1	ATC.70	Highway	7	19	15	19	4.0	<2.0	480	1920	**<1.0**
11-29	ATC.17	Local	8	24	16	24	4.0	52.7	480	1920	**27.5**
11-29	ATC.18	Local	8	22	16	22	4.0	132	480	1920	**69.0**
11-29	ATC.20	Local	8	20	16	20	4.0	43.4	480	1920	**22.6**
11-29	ATC.19	Local	8	20	16	20	4.0	68.9	480	1920	**35.9**
11-30	ATC.36	Local	8	5	16	5	4.0	59.6	480	1920	**31.1**
11-30	ATC.38	Local	8	8	16	8	4.0	127	480	1920	**66.0**
11-30	ATC.39	Local	8	10	16	10	4.0	83.8	480	1920	**43.6**
11-30	ATC.37	Local	8	6	16	6	4.0	35.8	480	1920	**18.6**
12-1	ATC.63	Local	9	9	17	9	4.0	119	480	1920	**62.2**
12-1	ATC.66	Local	7	58	15	58	4.0	65.0	480	1920	**33.8**
11-29	ATC.11	Local Cab	8	46	16	46	4.0	36.1	480	1920	**18.8**

Table 2. Concentrations of Organic Carbon (Cont'd)
Advance Transportation Company
November 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
11-30	ATC.40	Local Cab	8	30	16	30	4.0	21.8	480	1920	**11.3**
12-1	ATC.65	Local Cab	9	28	17	28	4.0	188	480	1920	**97.9**
11-29	ATTC.3	Local Cab (Total)	8	46	19	58	4.0	105	672	2688	**39.0**
11-30	ATTC.8	Local Cab (Total)	8	30	18	38	4.0	32.9	608	2432	**13.5**
12-1	ATTC.11	Local Cab (Total)	9	28	18	28	4.0	264	540	2160	**122**
11-29	ATC.16	Mechanic	7	7	15	7	4.0	60.2	480	1920	**31.4**
11-29	ATC.13	Mechanic	7	12	15	12	4.0	61.0	480	1920	**31.7**
11-29	ATC.15	Mechanic	7	10	15	10	4.0	118	480	1920	**61.3**
11-29	ATC.14	Mechanic	7	10	15	10	4.0	418	480	1920	**218**
11-30	ATC.34	Mechanic	7	8	15	2	4.0	70.8	474	1896	**37.3**
11-30	ATC.31	Mechanic	7	4	15	4	4.0	73.2	480	1920	**38.1**
11-30	ATC.32	Mechanic	7	5	15	5	4.0	65.2	480	1920	**33.9**
11-30	ATC.33	Mechanic	7	6	11	3	4.0	83.5	237	948	**88.1**
11-31	ATC.53	Mechanic	7	5	15	5	4.0	571	480	1920	**298**
11-31	ATC.54	Mechanic	7	3	15	3	4.0	95.4	480	1920	**49.7**
11-31	ATC.59	Mechanic	7	5	15	5	4.0	166	480	1920	**86.5**
11-31	ATC.60	Mechanic	7	4	15	4	4.0	175	480	1920	**91.3**
11-29	ATC.57	Residential	16	40	23	35	4.0	<2.0	415	1660	**<1.2**
11-29	ATC.21A	Residential	6	43	14	43	4.0	<2.0	480	1920	**<1.0**
11-30	ATC.41	Residential	7	55	13	57	4.0	<2.0	362	1448	**<1.4**
11-30	ATC.67	Residential	17	15	0	1	4.0	<2.0	406	1624	**<1.2**
12-1	ATC.69	Residential	7	27	15	27	4.0	<2.0	480	1920	**<1.0**
11-28	ATC.7	Road	18	37	22	24	4.0	24.1	227	908	**26.6**
11-28	ATC.8	Road	20	2	4	2	4.0	34.2	480	1920	**17.8**
11-28	ATC.9	Road	20	10	4	10	4.0	40.4	480	1920	**21.0**
11-28	ATC.10	Road	20	14	4	5	4.0	72.6	471	1884	**38.6**
11-29	ATC.24	Road	20	3	4	3	4.0	23.4	480	1920	**12.2**
11-29	ATC.25	Road	20	7	4	7	4.0	25.7	480	1920	**13.4**
11-29	ATC.23	Road	19	58	3	58	4.0	40.9	480	1920	**21.3**
11-29	ATC.22	Road	19	22	3	22	4.0	2.7	480	1920	**1.4**
11-30	ATC.48	Road	19	58	3	58	4.0	89.2	480	1920	**46.4**
11-30	ATC.49	Road	20	7	4	7	4.0	46.6	480	1920	**24.2**
11-30	ATC.50	Road	18	35	2	35	4.0	36.6	480	1920	**19.0**
11-30	ATC.51	Road	19	59	3	59	4.0	28.0	480	1920	**14.6**

Table 2. Concentrations of Organic Carbon (Cont'd)
Advance Transportation Company
November 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
11-28	ATC.6	Road Cab	18	38	2	38	4.0	38.0	480	1920	**19.8**
11-29	ATC.21	Road Cab	19	30	3	30	4.0	42.2	480	1920	**22.0**
11-30	ATC.52	Road Cab	18	38	2	38	4.0	59.4	480	1920	**30.9**
11-28	ATTC.2	Road Cab (Total)	18	38	2	38	4.0	54.3	480	1920	**28.3**
11-29	ATTC.5	Road Cab (Total)	19	30	3	30	4.0	82.9	480	1920	**43.2**
11-30	ATTC.10	Road Cab (Total)	18	40	2	40	4.0	95.1	480	1920	**49.5**
11-29	ATC.12	Shop Area	7	0	15	0	4.0	58.8	480	1920	**30.6**
11-30	ATC35	Shop Area	6	55	15	2	4.0	64.5	487	1948	**33.1**
11-31	ATC.61	Shop Area	6	52	14	56	4.0	58.1	484	1936	**30.0**
11-29	ATTC.4	Shop Area (Total)	7	0	15	17	4.0	139	497	1988	**70.0**
11-30	ATTC.7	Shop Area (Total)	6	55	14	59	4.0	141	484	1936	**72.8**
11-31	ATTC.12	Shop Area (Total)	6	52	14	55	4.0	107	483	1932	**55.6**

Table 3. Concentrations of Nitrogen Dioxide
Advance Transportation Company
November 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Mass (ug NO2)	Mass (nmoles)	Time (hr)	Concentration (ppm NO2)
11-28	AT2-2	Dock	15	41	23	48	-0.03	-0.65	8.1	-0.03
11-28	AT2-3	Dock	15	34	23	23	-0.03	-0.65	7.8	-0.04
11-28	AT2-1	Dock	15	31	23	23	0.065	1.41	7.9	0.08
11-29	AT2-14	Dock	15	36	23	23	0.015	0.33	7.8	0.02
11-29	AT2-13	Dock	15	40	23	25	-0.03	-0.65	7.8	-0.04
11-30	AT2-24	Dock	16	5	23	42	-0.03	-0.65	7.6	-0.04
11-30	AT2-23	Dock	16	4	23	23	0.095	2.07	7.3	0.12
11-30	AT2-22	Dock	16	3	23	50	-0.03	-0.65	7.8	-0.04
11-30	AT2-21	Dock	15	46	23	32	0.025	0.54	7.8	0.03
11-29	AT2-8	Local	8	20	20	15	0.055	1.20	11.9	0.04
11-29	AT2-9	Local	8	22	18	20	-0.03	-0.65	10.0	-0.03
11-29	AT2-7	Local	8	20	18	25	0.085	1.85	10.1	0.08
11-30	AT2-19	Local	8	6	18	36	0.065	1.41	10.5	0.06
11-30	AT2-20	Local	8	5	18	46	0.045	0.98	10.7	0.04
12-1	AT2-32	Local	9	9	18	27	0.105	2.28	9.3	0.11
12-1	AT2-31	Local	7	11	18	19	0.125	2.72	11.1	0.11
12-1	AT2-30	Local	7	58	16	46	0.005	0.11	8.8	0.01
12-1	AT2-29	Local	9	9	18	15	0.045	0.98	9.1	0.05
11-29	AT2-12	Mechanic	7	10	15	10	0.045	0.98	8.0	0.05
11-29	AT2-10	Mechanic	7	7	15	10	0.365	7.93	8.1	0.43
11-29	AT2-11	Mechanic	7	10	15	10	0.015	0.33	8.0	0.02
11-30	AT2-18	Mechanic	7	5	15	10	0.315	6.85	8.1	0.37
11-31	AT2-36	Mechanic	7	4	15	6	0.355	7.72	8.0	0.42
11-31	AT2-35	Mechanic	7	3	15	9	0.405	8.80	8.1	0.47
11-31	AT2-34	Mechanic	7	5	15	11	0.335	7.28	8.1	0.39
11-31	AT2-33	Mechanic	7	5	15	6	0.285	6.20	8.0	0.34
11-28	AT2-5	Road	18	37	5	0	-0.03	-0.65	10.4	-0.03
11-28	AT2-4	Road	20	14	8	37	0.055	1.20	12.4	0.04
11-28	AT2-6	Road	20	10	6	0	-0.03	-0.65	9.8	-0.03
11-29	AT2-15	Road	19	58	6	20	0.015	0.33	10.4	0.01
11-29	AT2-16	Road	19	22	8	0	0.105	2.28	12.6	0.08
11-30	AT2-28	Road	19	59	4	35	0.015	0.33	8.6	0.02
11-30	AT2-27	Road	19	58	5	30	-0.03	-0.65	9.5	-0.03
11-30	AT2-26	Road	20	7	5	35	-0.03	-0.65	9.5	-0.03
11-30	AT2-25	Road	18	35	4	30	-0.03	-0.65	9.9	-0.03

Table 4. Concentrations of Nitric Oxide
Advance Transportation Company
November 1988

Date	Sample Number	Job/Area	Time Start		Stop		Mass (ug NOx)	Conc NO2 (ppm)	Mass (nmoles)	Time (hr)	Concentratio (ppm NO)
11-28	ATX-2	Dock	15	41	23	48	0.02	<0.03	0.43	8.1	**0.02**
11-28	ATX-3	Dock	15	34	23	23	<0.02	<0.04	<0.43	7.8	**<0.02**
11-28	ATX-1	Dock	15	31	23	23	0.03	0.08	0.65	7.9	**<0.03**
11-29	ATX-14	Dock	15	36	23	23	0.11	0.02	2.39	7.8	**0.09**
11-29	ATX-13	Dock	15	40	23	25	0.03	<0.04	0.65	7.8	**0.03**
11-30	ATX-24	Dock	16	5	23	42	0.02	<0.04	0.43	7.6	**0.02**
11-30	ATX-23	Dock	16	4	23	23	0.01	0.12	0.22	7.3	**<0.08**
11-30	ATX-22	Dock	16	3	23	50	0.04	<0.04	0.87	7.8	**0.04**
11-30	ATX-21	Dock	15	46	23	32	<0.02	0.03	<0.43	7.8	**<0.04**
11-29	ATX-8	Local	8	20	20	15	0.04	0.04	0.87	11.9	**<0.01**
11-29	ATX-9	Local	8	22	18	20	0.03	<0.03	0.65	10.0	**0.02**
11-29	ATX-7	Local	8	20	18	25	0.1	0.08	2.17	10.1	**0.01**
11-30	ATX-19	Local	8	6	18	36	<0.02	0.06	<0.43	10.5	**<0.06**
11-30	ATX-20	Local	8	5	18	46	0.05	0.04	1.09	10.7	**0.00**
12-1	ATX-32	Local	9	9	18	27	0.07	0.11	1.52	9.3	**<0.03**
12-1	ATX-31	Local	7	11	18	19	0.06	0.11	1.30	11.1	**<0.04**
12-1	ATX-30	Local	7	58	16	46	0.05	0.01	1.09	8.8	**0.04**
12-1	ATX-29	Local	9	9	18	15	0.14	0.05	3.04	9.1	**0.08**
11-29	ATX-12	Mechanic	7	10	15	10	0.19	0.05	4.13	8.0	**0.13**
11-29	ATX-10	Mechanic	7	7	15	10	0.41	0.43	8.91	8.1	**0.04**
11-29	ATX-11	Mechanic	7	10	15	10	0.32	0.02	6.96	8.0	**0.28**
11-30	ATX-18	Mechanic	7	5	15	10	0.41	0.37	8.91	8.1	**0.09**
11-31	ATX-36	Mechanic	7	4	15	6	0.42	0.42	9.13	8.0	**0.06**
11-31	ATX-35	Mechanic	7	3	15	9	0.45	0.47	9.78	8.1	**0.04**
11-31	ATX-34	Mechanic	7	5	15	11	0.4	0.39	8.70	8.1	**0.06**
11-31	ATX-33	Mechanic	7	5	15	6	0.34	0.34	7.39	8.0	**0.05**
11-28	ATX-5	Road	18	37	5	0	<0.02	<0.03	<0.43	10.4	**<0.01**
11-28	ATX-4	Road	20	14	8	37	0.02	0.04	0.43	12.4	**<0.02**
11-28	ATX-6	Road	20	10	6	0	0.01	<0.03	0.22	9.8	**0.01**
11-29	ATX-15	Road	19	58	6	20	0.08	0.01	1.74	10.4	**0.05**
11-29	ATX-16	Road	19	22	8	0	<0.02	0.08	<0.43	12.6	**<0.07**
11-30	ATX-28	Road	19	59	4	35	<0.02	0.02	<0.43	8.6	**<0.03**
11-30	ATX-27	Road	19	58	5	30	<0.02	<0.03	<0.43	9.5	**<0.03**
11-30	ATX-26	Road	20	7	5	35	<0.02	<0.03	<0.43	9.5	**<0.02**
11-30	ATX-25	Road	18	35	4	30	0.01	<0.03	0.22	9.9	**0.01**

Table 5. Concentrations of Respirable Dust
Advance Transportation Company
November 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentratio (ug/m3)
11-28	FW4637	Dock Area	16	13	23	32	1.7	5	439	746	**6.7**
11-29	FW5197	Dock Area	15	57	23	30	1.7	45	453	770	**58.4**
11-30	FW4651	Dock Area	15	34	23	12	1.7	15	458	779	**19.3**
11-29	FW4639	Local Cab	8	46	19	58	1.7	35	672	1142	**30.6**
11-30	FW4656	Local Cab	8	30	18	35	1.7	25	605	1029	**24.3**
12-1	FW4657	Local Cab	9	28	18	27	1.7	155	539	916	**169.2**
11-28	FW4632	Road Cab	18	38	7	20	1.7	35	762	1295	**27.0**
11-29	FW5198	Road Cab	19	30	3	30	1.7	135	480	816	**165.4**
11-30	FW4652	Road Cab	18	39	2	39	1.7	25	480	816	**30.6**
11-29	FW4638	Shop Area	7	0	15	17	1.7	55	497	845	**65.1**
11-30	FW5196	Shop Area	6	55	14	59	1.7	65	484	823	**79.0**
11-31	FW4650	Shop Area	6	52	14	57	1.7	75	485	825	**91.0**