HETA 87-232-1948
FEBRUARY 1989
CONSOLIDATED FREIGHTWAYS
POCONO SUMMIT, PENNSYLVANIA

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I. SUMMARY

On April 9, 1987, NIOSH received a request for a Health Hazard Evaluation from the International Brotherhood of Teamsters, Chauffeurs, Warehousemen & Helpers of America, which represents the workforce at the Consolidated Freightways, Inc., Pocono Summit, Pennsylvania, break-bulk trucking terminal. The union requested evaluation of (a) potential exposures of the dock workers to exhaust emissions from diesel-powered forklift trucks, and (b) reported health effects (such as irritation) that its members thought were related to these exposures. NIOSH investigators conducted an environmental and medical survey at the facility on September 27 and 28, 1987.

The environmental survey consisted mainly of air sampling for selected contaminants present in diesel-engine exhaust considered to represent the greatest health risks. Area air samples were collected for carbon dioxide, carbon monoxide, sulfur dioxide, nitrogen dioxide, total oxides of nitrogen, formaldehyde, volatile aliphatic and aromatic hydrocarbons, particulate solvent-extractable fraction, polynuclear aromatic hydrocarbons (PAHs), particulate (total, respirable, and sub-micron), sulfuric acid, and elemental carbon (as an index of overall diesel-exhaust exposure). The airborne concentrations of all components measured were well below all relevant individual evaluation criteria, except in the case of the solvent-extractable fraction of diesel particulate when compared with the NIOSH criterion for coal-tar pitch materials. Although this criterion is not directly applicable to diesel particulate, it is a useful guideline due to these materials' similarities and the carcinogenic potential of each of them.

NIOSH medical investigators interviewed 21 workers identified as being symptomatic in order to substantiate complaints previously documented as being caused by diesel-exhaust exposure. These included 15 workers who constituted half of the midnight shift. All workers interviewed (and thus at least 50% of the midnight shift) reported upper respiratory tract irritation. Other frequently reported symptoms were eye irritation, cough productive of black-tinged sputum, and sore throat. All persons interviewed stated that the symptoms abated during extended periods away from work.

Based upon reported acute irritative health effects consistent with exposure to diesel exhaust, and exposures to potentially carcinogenic material, the NIOSH investigators concluded that there is a potential health hazard associated with the exposures to diesel engine exhaust at this facility. Recommendations for reducing exposures are made in Section VI of this report.

KEYWORDS: SIC 4213 (Trucking, Except Local), diesel exhaust exposures, polynuclear aromatic hydrocarbons, benzene-soluble particulate fraction

II. INTRODUCTION/BACKGROUND

On April 9, 1987, NIOSH received a valid request for a Health Hazard Evaluation (HHE) from the International Brotherhood of Teamsters, Chauffeurs, Warehousemen & Helpers of America, which represents the workforce at the Consolidated Freightways, Inc., Pocono Summit, Pennsylvania, break-bulk trucking terminal. This union asked NIOSH to evaluate (a) potential exposures of the dock workers to exhaust emissions from the diesel-powered forklift trucks in use at the terminal, and (b) reported health effects that union members thought were related to these exposures. The most commonly reported health effects were respiratory and eye irritation, the production of black-colored mucus or phlegm, other respiratory difficulties, and headaches. The union indicated that the worst-case exposures occur each week during the Sunday-night-to-Monday-morning night shift, because operations (and thus almost all of the forklifts) are at that time concentrated only in the east end of the terminal.

The Pocono Summit terminal occupies a very long, relatively narrow building constructed largely of steel. The majority of the building's floor space is devoted to the dock area, which is a single-story "high bay." The remainder of the building includes offices, repair shops, lunchroom, restrooms, etc. The majority of the wall space in the dock area is occupied by 198 large door openings the size of a truck trailer's rear door opening; trailers are backed up to these doors for unloading and loading.

This terminal is referred to as a "break-bulk" type because its function is to receive large, long distance loads, and break them down into smaller, short-distance loads. The dock workers use forklift trucks to move cargo around the dock and into and out of trailers. Total employment at this facility, which operates 24 hours per day, 7 days per week, on three shifts, is about 350 to 400. In addition to a few mechanics, thirty or more dockmen work during each shift (the number varies by shift).

NIOSH investigators conducted an industrial hygiene and medical survey at the facility on September 27 and 28, 1987, and a letter describing the activities conducted during this visit, with preliminary results and conclusions, was sent on October 23, 1987, to company and union representatives. On June 17, 1988, a letter serving as an interim report pending the completion of the current report, but summarizing the final results of the evaluation, was sent to the same parties.

III. EVALUATION DESIGN AND METHODS

A. Environmental

The environmental survey consisted of an inspection of the terminal facilities and activities, and air sampling during the night shift for eleven selected substances or classes of substances present in diesel-engine exhaust emissions. The substances selected were those considered to present the most significant health risks, based on quantities produced and toxicology, among those for which sampling methods were available. There is no single method to measure overall exposure to whole diesel exhaust.

Short-term area air samples for five components of diesel-engine exhaust emissions were collected in the dock area, and one such sample was collected for carbon dioxide (CO_2) outside, near the building, to obtain a background level for this compound. In the dock area, three samples (two near Door #19, at the eastern end of the dock, and one near Door #59, just east of the center of the dock) each for CO_2, carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and total oxides of nitrogen (NO_x) were collected. All of these samples were collected using Dräger* detector tubes and pump; the detector tubes used for these analytes were models CO_2 0.01%/a, CO 5/c, SO_2 1/a, NO_2 0.5/c, and Nitrous Fumes 0.5/a, respectively.

Long-term (full- and partial-shift) area air samples for ten components of diesel-engine exhaust emissions were collected in the dock area. At least two samples for each component were collected, one near Door #19 and one near Door #59; all samples collected at each of these two locations were side-by-side with one another, and with the short-term samples collected at these locations (noted above). For some components, more than one sample at the same location was collected to allow for the use of more than one collection and/or analytical technique. All long-term air samples were submitted for analysis to the NIOSH analytical laboratory, or to a NIOSH contract analytical laboratory.

Samples for eight of the above ten components were collected using personal air sampling pumps drawing air at known rates through various sampling media, including tubes packed with solid sorbents, filters in cassettes, and impingers containing liquid absorbing solutions. These eight components included formaldehyde, SO_2, volatile aliphatic and aromatic hydrocarbons, particulate solvent-extractable fraction, volatile and particulate-borne solvent-extractable polynuclear aromatic hydrocarbons (PAHs), particulate (total, respirable, and sub-micron), sulfuric acid (H_2SO_4), and elemental carbon (as an index for overall exposure to diesel-engine exhaust emissions). The flow rates, sampling media, and analytical techniques used for each of these eight components are provided in Table I.

For the remaining two of the above mentioned ten components, NO_2 and NO_x, long-term samples were collected with passive monitoring devices that utilize diffusion to transport analytes to appropriate absorbing media. In accordance with NIOSH Method 6700 [1], the media for NO_2 is a triethanolamine-coated screen with which the NO_2 reacts; the derivative formed is then analyzed spectrophotometrically. A modified version of this method [2] is used for NO_x; a pad impregnated with chromic acid is inserted into the sampler (along with the triethanolamine-coated screen) to oxidize NO to NO_2, thus allowing the total of these to be measured.

B. Medical

The NIOSH medical investigators interviewed 21 workers who were selected by the union because they were thought to have work-related symptoms. This group of symptomatic workers was interviewed to substantiate complaints that have been documented in the medical literature as being caused by diesel exhaust.

IV. EVALUATION CRITERIA

A. Toxicological Effects of Diesel Exhaust Emissions

The exhaust emissions from diesel engines are composed of both gaseous and particulate fractions. The gaseous components include oxides of sulfur, nitrogen dioxide, nitric oxide, carbon monoxide, carbon dioxide, and hydrocarbons [3]. The particulate fraction (soot) is composed of solid carbon cores, produced during the combustion process, that tend to form aggregates, the largest of which are in the respirable range (more than 95% are less than 1 micron in size) [3]. It has been estimated that as many as 18,000 different substances from the combustion process can be adsorbed onto diesel exhaust particulates [3]. This adsorbed material contains 15% to 65% of the total particulate mass and includes such compounds as polynuclear aromatic hydrocarbons (PAHs). Among the polycyclic hydrocarbons are a number of known mutagens and carcinogens [3].

Many of the individual components of diesel exhaust are known to have toxic effects. The following health effects have been associated with some components found in diesel exhaust: 1) pulmonary irritation from nitrogen dioxide; 2) irritation of the mucous membranes and eyes from sulfur dioxide, phenol, sulfuric acid, sulfate aersols, and acrolein; and, 3) cancer in animals from polycyclic hydrocarbons.

Several recent animal studies in rats and mice confirm an association between cancer and exposure to whole diesel exhaust [4]. The primary site identified with the carcinogenic or tumorigenic responses following inhalation exposure is the lung. Limited epidemiologic evidence suggests an association between occupational exposure to diesel engine emissions and lung cancer [4]. Based on the consistency of current toxicological and epidemiological evidence, a potential occupational carcinogenic hazard exists from human exposure to diesel exhaust. Tumor induction is associated with diesel exhaust particulates, and limited evidence suggests that the gaseous fraction of diesel exhaust may be carcinogenic as well [3]. NIOSH recommends that because of its carcinogenic potential, exposure to diesel emissions be reduced to the lowest feasible limits [3].

B. Environmental Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLVs usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended standards, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

Table II contains the Permissible Exposure Limits promulgated by the Occupational Safety and Health Administration (OSHA PELs) [5], the ACGIH TLVs [6], and the NIOSH Recommended Exposure Limits (NIOSH RELs) [7] relevant to as many as possible of the substances, or classes of substances, for which air samples were collected in this evaluation.

V. RESULTS AND DISCUSSION

A. Environmental

The inspection of the terminal facilities and activities revealed that the east end of the dock does not have any mechanical ventilation; the west end has several exhaust fans in the roof that provide dilution ventilation. Natural ventilation throughout the dock will occur through numerous openings around the doors (especially during the warmer months, when the "bumpers," which are rubber surfaces used to seal the openings between trailers parked at the dock and the door openings, are removed) and through any doors that are not occupied by a trailer. Both union and management personnel indicated that few if any of the doors in the east end are typically left unoccupied during the shift in question, and that the three or four such open doors seen during that shift, on the night of the survey, may have been somewhat unusual. No specific provision for make-up air for the roof exhaust fans is present; rather, make-up air will enter through the previously noted openings. No other air handling or conditioning systems are used in the dock area.

The inspection also revealed that among a portion of the forklift truck operators it was typical practice, at least on the night of the survey, to leave the engines idling, even when the units were left unattended. During the night shift in question, 4 forklift trucks (out of approximately 18) were not in use; both union and management personnel indicated that this was typical for this specific shift. All four were older models (which are considered by the union personnel to be emitters of relatively high levels of pollutants); about five of the remaining forklifts in use were newer models. Finally, the inspection also revealed that most horizontal surfaces in the dock were covered by a thin film of black, soot-like material.

The measured concentrations of each of the five compounds for which short-term area air samples were collected are all well below their relevant individual evaluation criteria enumerated in Table II; the results of these samples are shown in Table III. Also, no significant elevation of the CO_2 level was detected in the dock area compared to the outdoor background level. Finally, no trend indicating that concentrations of most of these contaminants were greater at one sampling location than at the other was apparent.

The results of the long-term area air samples are shown in Tables IV, V, and VI. As with the short-term sampling results, no trend indicating that concentrations of most of these contaminants were greater at one sampling location than at the other was apparent. The results for formaldehyde, toluene, SO_2, H_2SO_4, and NO_2 (Table IV) and for the individual PAHs benzo[a]pyrene, naphthalene, and chrysene (Table V) are below all relevant evaluation criteria. The particulate sulfate results (Table IV) may be grouped with the corresponding H_2SO_4 results, but the measured total airborne concentrations are still below the relevant evaluation criteria (for H_2SO_4).

Airborne (total and respirable) particulate results (Table V) are below the evaluation criteria listed in Table II. However, the "nuisance" particulate criteria are generally applied to biologically "inert" materials. Particulates emitted from diesel engines bear chemical substances of toxicological significance. Therefore, the "nuisance" particulate criteria is not adequate in this case. Also, the sub-micron fraction (less than 1 um particle size) has no evaluation criterion. However, these measurements are useful to illustrate the proportion of the particulate exposures which are due to direct diesel exhaust emissions (more than 95% of these particles are less than 1 micron in size [3]) compared with other sources, such as re-entrained or agglomerated exhaust-emission particles or other sources of dust. In this facility, the larger particles, from sources other than direct emissions, appeared to predominate during the survey period. These measurements are also useful to illustrate the proportion of the total particulate concentration accounted for by the other particulate-borne materials measured (e.g., sulfates and solvent extractables).

It should be noted here that the environmental evaluation criteria listed in Table II are directly applicable to personal exposure levels, but the sampling conducted during this HHE measured general-area levels. Still, the measured area levels of the diesel exhaust-emission components mentioned thus far in this discussion were well below relevant criteria. While it is plausible that some personal exposures were greater than the area levels due to such effects as the operation of forklift trucks inside trailers, it is unlikely that these exposures were sufficiently elevated to cause overexposures to these individual components.

It should also be noted here that the measured levels of the various diesel exhaust-emission components represent those found under the conditions on the night of the survey only, and may vary at other times. They may have been slighly affected by the atypical number of doors left open (3 or 4 instead of roughly 1, out of the 198 in the facility) and the observed lack of adherence to the policy calling for shut-off of idling forklift trucks. Still, the measured area levels of the individual components mentioned thus far in this discussion were well below relevant criteria, with only NO_2 levels within even an order of magnitude of an evaluation criterion. While it is plausible that levels sometimes exceed those measured, it is unlikely that they ever increase sufficiently to cause overexposures to these individual components.

The evaluation criteria for coal-tar pitch materials (Table II) are based on the assumption that total benzene- (or cyclohexane-) soluble fractions of airborne total particulate samples approximate the total of all particulate-borne PAHs present. A similar assumption is made regarding the benzene- and acetonitrile-extractable fractions of airborne samples of diesel-engine exhaust particulate emissions. This forms the basis for comparing the results (Table V) for benzene- and acetonitrile-extractable fractions of total diesel exhaust particulate (which have no evaluation criteria) with the evaluation criteria for coal-tar pitch materials. However, such an approach is not without problems. Although diesel-engine exhaust particulate emissions are similar to coal-tar pitch materials because they are both carbonaceous and known to be PAH-containing, it is not known how hazardous the material extracted from these particulates is, compared to that from coal-tar pitch. Therefore, the evaluation criteria for coal-tar pitch materials are not directly comparable with these results, and should be considered only guidelines for evaluation. Neither the benzene- or acetonitrile-extractables, any individual PAH, nor the total (in any one sample) of individual PAH concentrations exceeds the evaluation criteria for benzene (or cyclohexane) solubles, except for that of sample ZF-6 (Table V), which exceeds the NIOSH REL (the result for sample ZF-5 is very close to the REL also). These materials' potential for carcinogenicity is the main toxicological concern, and no safe level has been demonstrated for a carcinogen. Therefore, despite the uncertainty of interpreting these data, a reduction in the exposures to these materials is desirable (see also the relevant footnotes for these materials in Table II), especially considering the possibility that exposures to these materials may at times be greater than the measured levels (as described above).

The results of the samples for elemental carbon in Table VI are not comparable with any existing evaluation criteria. Elemental carbon has been proposed as an index of overall exposure to diesel-engine exhaust emissions, but the significance of the measured airborne concentrations is unclear at this time. The samples were collected primarily to help NIOSH investigators assess the usefulness of this measurement for the evaluation of exposures to diesel-engine exhaust emissions. The results are presented to ensure the completeness of this report, and to ensure that they are properly documented should they become relevant for future studies in this area.

A major concern of the employees in requesting this HHE was the presence of irritant substances. The airborne concentrations of several irritants were measured and compared with irritation-based evaluation criteria, but only NO_2 levels (averaging 0.14 ppm during the full shift, and less during the short-term sampling periods) were measured within an order of magnitude of such a criterion (NIOSH REL of 1 ppm for a 15-min ceiling).

B. Medical

The group of 21 workers interviewed consisted of: 14 dockmen and 1 mechanic from the 12:00 midnight to 8:30 a.m. shift, 1 dockman from the 4:00 p.m. to 12:30 a.m. shift, and 5 dockmen from the 8:00 a.m. to 4:30 p.m. shift. The employees work five consecutive days each week. All of the workers interviewed were male, ages 24-61 (average = 39) years. Their work experience at the company ranged from 3 months to 10 years. Fifteen (71%) of those interviewed smoked cigarettes. One worker, a non-smoker, had a history of allergic bronchitis for which he was under medical care.

All 21 workers reported having black soot in their nostrils by the end of the shift, and complained of upper respiratory tract irritation. The most frequently reported symptoms were:

1. Nasal congestion, nasal irritation, and post-nasal drip (all 21 workers)

2. Eye irritation or lacrimation (16)

3. Cough productive of black-tinged sputum (15)

4. Sore throat (12)

Three or fewer workers reported hoarseness, increased frequency of colds, headaches, shortness of breath, dry cough, nosebleeds, and chest congestion.

All workers interviewed said that they were experiencing sypmtoms at the present time. They also noted that the symptoms are worse during the winter months (when the dock is kept "closed up" as much as possible and the forklift engines are allowed to run continuously). All stated that the symptoms greatly improved or abated on weekends away from work and during vacation periods. Twenty workers related the onset of their symptoms to a period of 1 to 4 months following replacement of propane-fueled forklift trucks with diesel-powered vehicles. Although we interviewed workers who were identified as having health complaints, the 15 interviewed night-shift workers represented about one-half of all workers on that shift. Thus, even if the workers not interviewed had no symptoms, symptom prevalences would range up to 50%.

The workers who were employed at the plant when the company began using diesel forklift trucks related the development of the symptoms of mucous membrane and upper respiratory irritation to the exhaust emissions from these trucks. Since diesel exhaust contains irritants, this seems reasonable, but no practical way of objectively confirming it was available. Scientific studies are currently being conducted on diesel exhaust, but the information on long-term adverse health effects of worker exposure to diesel exhaust is inconclusive at this time.

The NIOSH investigators have concluded that, despite the relatively low concentrations of the measured airborne contaminants, workers reported acute irritative health effects consistent with the symptoms of exposure to whole diesel exhaust. The exact cause of the effects is uncertain due to the absence of exposures in excess of the relevant criteria. Only NO_2 levels were measured within even an order of magnitude of an irritation-based evaluation criterion. It may be that additive or synergistic effects among the various components of diesel exhaust, the presence of unrecognized component(s), and/or characteristics related to the small particulate in diesel fume (e.g., irritation associated with the size or shape of the particles, or the ability of the fine particulate to penetrate the lower regions of the lung, possibly more efficiently carrying certain adsorbed components to these areas than they otherwise would be carried), or some other unrecognized factor(s) are responsible for the health effects found. However, no further evidence is available at this time to support any of these specific ideas.

VI. RECOMMENDATIONS

Because of the presence of acute irritant health effects of diesel exhaust, and the potential for long-term health effects (primarily, the potential carcinogenic risk), measures to reduce exposures should be instituted. Unfortunately, the environmental results do not provide information indicating the extent to which the exposures should be reduced. Therefore, a practical solution to this problem is to reduce the exposures to a sufficient extent that irritative symptoms are alleviated. The following are several measures to reduce exposures.

1. Two changes in work practices should be instituted. First, whenever the forklift trucks are left unattended for more than the briefest of periods, engines should be shut off. Management has stated that this is current policy, but it is unclear to what extent this policy is normally followed. Also, whenever any forklifts are to be left unused during a shift (as happened at the time of the air sampling), older-model units should be selected for this (as was done on the night of the survey).

2. Management personnel indicated that roof exhaust fans have been ordered for the east end of the terminal's dock area. These should be installed, and their effectiveness subsequently evaluated. (An indicator of fan effectiveness will be the reduction of airborne concentrations of pollutants, and thus the subsequent measurement of these concentrations should be considered. However, since the degree to which levels must be reduced is not known, one indicator of effectiveness will be the reduction of the incidence of reported health effects, as noted above.) Also, the assistance of forklift manufacturer representatives should be sought, as has reportedly been done in the past, to decrease the rate of exhaust emissions from the forklift trucks (particularly the older models and those considered to be excessive emitters).

3. A more effective alternative to the above control measures, which would reduce or eliminate exposure to the various diesel-engine exhaust-stream components, would be to phase out the use of diesel-powered forklift trucks in favor of propane-powered units (or units powered by other, less polluting, fuels). Caution would be needed before undertaking this alternative, to be sure that emissions from the replacement units did not create a new hazard (e.g., relatively high CO emissions from propane-fueled engines).

Additionally, a health and safety committee should be established to address the health concerns of the workers and promote a safer workplace. This group should include union and management representation.

VII. REFERENCES

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IX. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are temporarily available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Consolidated Freightways, Inc.
2. International Brotherhood of Teamsters, Chauffeurs, Warehousemen & Helpers of America
3. Teamsters' Local No. 229
4. OSHA, Region III
5. NIOSH, Cincinnati Region

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

TABLE I

Summary of Long-term Active Sampling and Analytical Methods
Consolidated Freightways, Inc.
Pocono Summit, Pennsylvania
HETA 87-232
28 September 1987

Contaminant	NIOSH Method Number [1]	Collection Medium	Volumetric Air Flow Rate (L/min) Used	Desorbing Solvent or Solution	Type of Analysis Used
Hydrocarbons, aliphatic and aromatic	1500/ 1501/ 1550*	Sorbent tube - charcoal	0.2	Carbon disulfide (CS_2)	Gas chromatograhy (GC) with flame-ionization detection (FID)
Formaldehyde	3500	Impinger - aqueous 1% sodium bisulfite solution	1.0		Chromotropic acid reaction, spectrophotometry
Sulfur dioxide and particulate sulfate	6004	Filters - mixed-cellulose-ester (MCE) membrane, followed by cellulose (impregnated with KOH)	1.5	aqueous 3mM sodium bicarbonate ($NaHCO_3$) and 2.4 mM sodium carbonate (Na_2CO_3) solution	Ion chromatograhy
Particulate sulfate and sulfuric acid	7903	Sorbent tube - glass-fiber filter plug followed by washed silica gel	0.5	aqueous 3mM $NaHCO_3$ and 2.4 mM Na_2CO_3 solution	Ion chromatograhy
Total particulate	0500	Filter - poly-vinyl chloride (PVC) membrane	2.0		Gravimetric
Respirable particulate	0600	Filter - PVC-membrane**	1.7		Gravimetric
Sub-micron particulate	***	Filter - PVC-membrane**	2.0		Gravimetric
Benzene-soluble fraction of particulate	5023	Filter - Polytetrafluoro-ethylene (PTFE) membrane	2.8	Benzene	Gravimetric
Acetonitrile-soluble fraction of particulate	5023	Filter - PTFE-membrane	2.8	Acetonitrile	Gravimetric
Polynuclear Aromatic Hydrocarbons (PAHs)	5515	Filter - PTFE-membrane, followed by sorbent tube - washed XAD-2 resin	2.0	Benzene	GC with FID
Polynuclear Aromatic Hydrocarbons (PAHs)	5506	Filter - PTFE-membrane, followed by sorbent tube - washed XAD-2 resin	2.0	Acetonitrile	High-performance liquid chromatograhy with fluorescence and ultra-violet detection
Elemental carbon	****	Filter - quartz-fiber**	****		Thermal-optical

* This method is a scan for all identifiable hydrocarbons, and is similar to all three of these NIOSH Methods.
** Preceded by an appropriate size selector.
*** Identical to NIOSH Methods 0500 and 0600 except for size selector.
**** Method under development; various flow rates were used as part of the development process.

TABLE II

Evaluation Criteria
Consolidated Freightways, Inc.
Pocono Summit, Pennsylvania
HETA 87-232
28 September 1987

Compound	ACGIH TLV		OSHA PEL		NIOSH REL	
	8-hr TWA (1) (ppm)	15-min STEL (2) (ppm)	8-hr TWA (ppm)	Ceiling (ppm)	10-hr TWA (ppm)	15-min Ceiling (ppm)
Benzo[a]pyrene	(A2)	-	-	-	-	-
Carbon Dioxide	5000	30000	5000	-	10000	30000 (10)
Carbon Monoxide	50	400	50	-	35 (8)	200 (0)
Formaldehyde	1 (A2)	2 (A2)	1	2 (15)	0.016 (6)(8)	0.1 (6)
Naphthalene	10	15	10	-	-	-
Nitric Oxide (NO)	25	-	25	-	25	-
Nitrogen Dioxide	3	5	-	5	-	1
Sulfur Dioxide	2	5	5	-	0.5	-
Toluene	100	150	200	300 (3)	100 (8)	200 (10)
	(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)
Chrysene	(A2)	-	0.2	-	(C)	-
Coal-tar pitch volatiles (benzene solubles)	0.2 (A1a)(4)	-	0.2 (7)	-	-	-
Coal-tar products (cyclohexane solubles)	-	-	-	-	0.1 (B)	-
Nuisance Dust, total	10	-	15	-	-	-
respirable	-	-	5	-	-	-
Sulfuric Acid	1	-	1	-	1	-

0. Ceiling, no defined time.
1. Time-Weighted Average.
2. Short-Term Exposure Limit.
3. Also includes a maximum peak of 500 ppm (exceeds the 300-ppm ceiling) for a maximum of 10 min during an 8-hr shift.
4. Also referred to as particulate polynuclear aromatic hydrocarbons (PPAHs) by ACGIH.
6. Designated as representing "the lowest feasible concentration that is reliably measurable" by NIOSH.
7. OSHA specifically includes only anthracene, benzo[a]pyrene, phenanthrene, acridine, chysene, and pyrene in the PEL.
8. 8-hr TWA.
10. 10-min Ceiling.
15. 15-min Ceiling.

A1a. Designated "human carcinogen" by ACGIH.
A2. Designated "suspected human carcinogen" by ACGIH.
B. NIOSH recommends treating this compound as a potential human carcinogen.
C. NIOSH recommends treating this compound as a potential human carcinogen and controlling it as an occupational carcinogen.

TABLE III

Results Of Short-Term Area Air Samples (Detector Tube Readings)
Consolidated Freightways, Inc.
Pocono Summit, Pennsylvania
HETA 87-232
28 September 1987

LOCATION	ANALYTE	TIME, a.m.	CONCENTRATION, ppm	NOTES
Near Door 19	SO_2	4:00	ND	
"	CO_2	4:03	300	
"	NO_x	4:10	3	
"	CO	4:20	ND	
"	NO_2	4:22	Trace	
Outside Bldg.	CO_2	5:00	200	Background
Near Door 59	CO_2	5:07	300	
"	CO	5:14	ND	
"	SO_2	5:20	ND	
"	NO_2	5:22	0.1	
"	NO_x	5:27	3	
Near Door 19	SO_2	6:35	ND	
"	NO_x	6:37	3	
"	NO_2	6:40	ND	
"	CO	6:45	ND	
"	CO_2	6:50	300	

TABLE IV

Results of Long-term Area Air Sampling for 7 Substances
Consolidated Freightways, Inc.
Pocono Summit, Pennsylvania
HETA 87-232
28 September 1987

Location:	Near door 59					Near door 19				
Substance	Sample Number	Start Time, a.m.	Stop Time, a.m.	Sample Volume, L	Concentration	Sample Number	Start Time, a.m.	Stop Time, a.m.	Sample Volume, L	Concentration
Formaldehyde	HCHO-1	1:24	7:55	350	0.0093 ppm	HCHO-2	1:03	7:58	390	0.0082 ppm
						HCHO-3	5:06	7:58	170	0.0099 ppm
Toluene	CT-1	1:26	8:17	82	<0.003 ppm*	CT-2	1:06	8:25	86	0.0078 ppm**
Sulfur Dioxide	S-1	1:28	8:17	610	0.025 ppm	S-2	1:07	8:25	660	0.036 ppm
Particulate Sulfate	AA-1				0.023 mg/m^3	AA-2				0.021 mg/m^3
Particulate Sulfate	H-1	1:27	8:17	210	0.025 mg/m^3	H-2	1:10	8:25	220	0.030 mg/m^3
Sulfuric Acid					0.001 mg/m^3					0.004 mg/m^3
Nitrogen Dioxide	NO2-1	1:24	8:30	NA@	0.13 ppm	NO2-2	1:01	8:30	NA@	0.15 ppm
Oxides of Nitrogen	NOX-1	1:24	8:30	NA@	@@	NOX-2	1:01	8:30	NA@	@@

* The "less than" (<) symbol indicates that the result is less than the analytical Limit of Detection (LOD)
** Result is below the Limit of Quantitation (LOQ) and thus is semi-quantitative
@ Diffusional monitor used to collect sample
@@ Unidentified sampling and/or analysis problem; result invalid

TABLE V

Results of Long-term Area Air Sampling for Particulates, Particulate (Solvent Extractible Fractions), and PAHs
Consolidated Freightways, Inc.
Pocono Summit, Pennsylvania
HETA 87-232
28 September 1987

Location:	Near door 59					Near door 19				
Substance	Sample Number	Start Time, a.m.	Stop Time, a.m.	Sample Volume, L	Concentration, mg/m^3	Sample Number	Start Time, a.m.	Stop Time, a.m.	Sample Volume, L	Concentration, mg/m^3
Sub-micron Particulates	FW 1061	1:29	8:17	780	0.05	FW 1044	1:07	8:25	880	0.02
Total Particulates	FW 9645	1:29	8:17	940	0.18	FW 9653	1:04	8:25	1100	0.32
Respirable Particulates	FW 1063	1:28	8:17	700	0.06	FW 1062	1:05	8:25	750	0.09
Benzene-soluble Fraction of Particulates	ZF-6	1:27	8:17	1100	0.13	ZF-7	1:08	8:25	1200	<0.04
Acetonitrile-soluble Fraction of Particulates	ZF-5	1:28	8:17	1100	0.096	ZF-8	1:07	8:25	1200	0.02

Polynuclear Aromatic Hydrocarbons (PAHs): Extracting Solvent/ Analysis Method: Filter/Tube Number: Time Start/Stop, a.m.: Sample Volume, L:	Benzene / GC/FID@ ZF-2 / PAH-2 1:27 / 8:17 820				Acetonitrile / HPLC,Fl/UV Dtn# ZF-1 / PAH-1 1:26 / 8:17 820				Benzene / GC/FID ZF-3 / PAH-3 1:06 / 8:25 880				Acetonitrile / HPLC, Fl/UV Dtn ZF-4 / PAH-4 1:06 / 8:25 880			
	Mass, ug			Concentration, ug/m^3	Mass, ng			Concentration, ug/m^3	Mass, ug			Concentration, ug/m^3	Mass, ng			Concentr., ug/m^3
	from filter	from tube	total		from filter	from tube	total		from filter	from tube	total		from filter	from tube	total	
Acenaphthylene	<0.5*	<0.5	<1.0	<1.2	NA+	NA	NA	NA	<0.5	<0.5	<1.0	<1.1	NA	NA	NA	NA
Acenaphthene	<0.5	<0.5	<1.0	<1.2	<100	<250	<350	<0.43	<0.5	<0.5	<1.0	<1.1	<100	<250	<350	<0.40
Fluorene	<0.5	<0.5	<1.0	<1.2	NA	NA	NA	NA	<0.5	<0.5	<1.0	<1.1	NA	NA	NA	NA
Phenanthrene	<0.5	<0.5	<1.0	<1.2	<100	<100	<200	<0.24	<0.5	<0.5	<1.0	<1.1	<100	<100	<200	<0.23
Anthracene	<0.5	<0.5	<1.0	<1.2	<100	<100	<200	<0.24	<0.5	<0.5	<1.0	<1.1	<100	<100	<200	<0.23
Fluoranthene	<0.5	<0.5	<1.0	<1.2	<25	<25	<50	<0.061	<0.5	<0.5	<1.0	<1.1	<25	<25	<50	<0.057
Pyrene	<0.5	<0.5	<1.0	<1.2	<25	<25	<50	<0.061	<0.5	<0.5	<1.0	<1.1	<25	<25	<50	<0.057
Benz(a)anthracene	<0.5	<0.5	<1.0	<1.2	<25	<25	<50	<0.061	<0.5	<0.5	<1.0	<1.1	<25	<25	<50	<0.057
Chrysene	<0.5	<0.5	<1.0	<1.2	<25	<25	<50	<0.061	<0.5	<0.5	<1.0	<1.1	<25	<25	<50	<0.057
Benzo(b)fluoranthene	<0.5	<0.5	<1.0	<1.2	<25	<25	<50	<0.061	<0.5	<0.5	<1.0	<1.1	<25	<25	<50	<0.057
Benzo(k)fluoranthene	<0.5	<0.5	<1.0	<1.2	<25	<25	<50	<0.061	<0.5	<0.5	<1.0	<1.1	<25	<25	<50	<0.057
Benzo(e)pyrene	<0.5	<0.5	<1.0	<1.2	<25	<25	<50	<0.061	<0.5	<0.5	<1.0	<1.1	<25	<25	<50	<0.057
Benzo(a)pyrene	<0.5	<0.5	<1.0	<1.2	<25	<35	<60	<0.073	<0.5	<0.5	<1.0	<1.1	<25	<35	<60	<0.068
Indeno(1,2,3-c,d)pyrene	<0.5	<0.5	<1.0	<1.2	<25	<50	<75	<0.091	<0.5	<0.5	<1.0	<1.1	<25	<50	<75	<0.085
Dibenz(a,h)anthracene	<0.5	<0.5	<1.0	<1.2	<25	<25	<50	<0.061	<0.5	<0.5	<1.0	<1.1	<25	<25	<50	<0.057
Benzo(g,h,i)perylene	<0.5	<0.5	<1.0	<1.2	<25	<25	<50	<0.061	<0.5	<0.5	<1.0	<1.1	<25	<25	<50	<0.057
Naphthalene	<0.5	3.9	3.9	4.8 (0.91 ppb)	NA	NA	NA	NA	<0.5	<0.5	<1.0	<1.1##	NA	NA	NA	NA

* The "less than" (<) symbol indicates that the result is less than the analytical Limit of Detection (LOD)
\+ NA indicates "not analyzed;" an acceptable standard analytical curve was not obtainable with this analytical method for this analyte due to poor detector response in the relevant concentration range
@ Gas chromatography with flame-ionization detection
\# High-performance liquid chromatography with fluorescence/ultraviolet detection

TABLE VI

Results of Long-term Area Air Sampling for Elemental Carbon
Consolidated Freightways, Inc.
Pocono Summit, Pennsylvania
HETA 87-232
28 September 1987

Location	Particle-size fraction	Pump	Sample Number	Time, a.m. Start	Stop	Flow (L/min)	Volume (L)	Concentration (ug/m^3)
Near door 19	respirable	Ganged Gilians	EC1	12:38	8:04	10.0	4480	50.1
	respirable	Ganged Gilians	EC2	12:38	8:05	10.1	4510	37.0
	sub-micron	Alpha 1	EC3	12:39	8:06	4.1	1800	55
	sub-micron	Alpha 1	EC4	12:39	8:06	4.1	1800	45
	respirable	Gast	EC5	12:42	8:08	11.1	4940	40.6
	respirable	Gast	EC6	12:42	8:08	11.0	4910	47.1
	respirable	SKC Universal	EC7	12:43	8:08	2.8	1200	52
	respirable	SKC Universal	EC8	12:44	8:09	3.1	1400	52
	total (open face)	SKC Universal	EC9	12:44	8:09	3.2	1400	84
	total (open face)	SKC Universal	EC10	12:44	8:10	3.2	1400	97
	sub-micron	SKC Universal	EC11	12:45	8:11	2.0	890	61
	sub-micron	SKC Universal	EC12	12:45	8:11	2.0	890	62
Near door 59	respirable	Ganged Gilians	EC13	1:03	8:26	9.7	4300	45
	respirable	Ganged Gilians	EC14	1:04	8:27	10.0	4440	46.0
	sub-micron	Alpha 1	EC15	1:04	8:28	4.0	1800	48
	sub-micron	Alpha 1	EC16	1:04	8:28	4.0	1800	50
	respirable	Gast	EC17	1:05	8:28	10.6	4710	45.8
	respirable	Gast	EC18	1:05	8:28	10.9	4820	34.4
	respirable	SKC Universal	EC19	1:06	8:29	2.9	1300	42
	respirable	SKC Universal	EC20	1:06	6:35	2.9	950	57
	sub-micron	SKC Universal	EC21	1:06	8:30	2.0	890	55
	sub-micron	SKC Universal	EC22	1:06	8:30	2.0	890	57
	total (open face)	SKC Universal	EC23	1:07	5:57	3.2	930	70
	total (open face)	SKC Universal	EC24	1:07	6:23	3.2	1000	62