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I. SUMMARY

On November 25, 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., Peru, Illinois, 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 that its members thought were related to these exposures. NIOSH investigators conducted an environmental and medical survey at the facility on March 23 and 24, 1988.

The environmental survey consisted mainly of air sampling for selected contaminants present in diesel-engine exhaust considered to represent the greatest health risks. Samples were collected for carbon dioxide, carbon monoxide, sulfur dioxide, sulfuric acid, nitrogen dioxide, total oxides of nitrogen, formaldehyde, volatile aliphatic and aromatic hydrocarbons, particulate (total, respirable, and sub-micron), particulate (solvent-extractable fraction), polynuclear aromatic hydrocarbons (PAHs), and elemental (and total organic) carbon (as an index of overall diesel-exhaust exposure). With the likely exception of exposures to the benzene-extractable fraction of diesel particulate compared to the NIOSH criterion for coal-tar pitch materials, airborne exposures to all components measured were below all relevant individual evaluation criteria. 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.

The medical survey consisted of a self-administered questionnaire distributed to all 115 (81 dock and 34 yard) workers present on the three shifts during the visit. The questionnaire addressed symptoms experienced at work, both on the day the questionnaire was completed, as well as during the preceding month, along with pertinent health and work information. Dock workers had higher prevalences of several symptoms, particularly headache, eye irritation, cough productive of sputum, and sore throat, than the presumably less-exposed yard workers.

Based upon the NIOSH recommendation that whole diesel exhaust be regarded as a potential occupational carcinogen, and upon the acute irritative health effects consistent with exposure to diesel exhaust reported by dock workers at this facility, the NIOSH investigators concluded that a potential health hazard exists here. 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 November 25, 1987, NIOSH received a 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., Peru, Illinois, 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 workers thought were related to these exposures. The most commonly reported health effects were respiratory tract 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 during the night shift, between Wednesday and Sunday of each week, when operations are heaviest.

The Peru 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 144 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. Employment at this facility, which operates 7 days per week, usually 24 hours per day on three shifts, was about 120 for all three shifts in a day, including over 80 dock workers and over 30 yard workers at the time of the survey. Twenty-five to thirty dock workers, about ten yard workers, and a few persons in other jobs work during each shift. The yard workers, as the name implies, work outside in the yard, connecting over-the-road trucks and trailers, refueling trucks, and performing other such duties. The over-the-road trucks are also diesel-powered, so these workers are also exposed to diesel-engine exhaust emissions, particularly during cold weather when the engines are normally left running to avoid the cold-start problems common to diesel engines.

NIOSH investigators conducted an industrial hygiene and medical survey at the facility on Wednesday and Thursday, March 23 and 24, 1988. A letter describing the activities conducted during this visit, with preliminary results and conclusions, was sent on April 13, 1988, to company and union representatives.

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 twelve selected substances or classes of substances present in diesel-engine exhaust emissions. The purpose of the sampling conducted was to initially characterize the airborne concentrations of the substances, allowing a determination of the need for any subsequent follow-up sampling for any of them. In an initial characterization of exposures, it is preferable to focus on a worst-case situation when one is identified. Therefore, the night shift was selected for sampling because it was designated as the worst-case exposure situation, as mentioned in the previous section of this report.

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. Although there is no single method to definitively measure overall exposure to whole diesel exhaust, air sampling was conducted for particulate elemental (and organic) carbon for use as an approximate index of overall exposure.

Short-term area air samples were collected in the dock area for four components of diesel-engine exhaust emissions: carbon dioxide (CO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), and total oxides of nitrogen (NO_x). Two samples were collected for each, one near Door #71, just west of the center of the dock, and one near Door #134, near the eastern end of the dock. All of these were collected using Dräger* detector tubes and pump; the detector tubes used for these analytes were models CO_2 0.01%/a, CO 0.5/c, NO_2 0.5/c, and Nitrous Fumes 0.5/a, respectively.

Long-term (full- and partial-shift) area air samples for nine components of diesel-engine exhaust emissions were collected in the dock area at two area-sampling locations, one near Door #71 and one near Door #134. These components are formaldehyde, NO_2, sulfur dioxide (SO_2), sulfuric acid (H_2SO_4), volatile aliphatic and aromatic hydrocarbons, particulate (total, respirable, and sub-micron), particulate (solvent-extractable fraction), volatile and particulate-borne solvent-extractable polynuclear aromatic hydrocarbons (PAHs), and particulate elemental (and organic) carbon (to establish the approximate index for overall exposure to diesel-engine exhaust emissions). At least one sample for each component was collected at each of the two sampling locations, and all samples (including the short-term samples noted above) collected at a given location were considered "side-by-side" with one another. 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 samples (except those for NO_2) 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. For these samples, the flow rate, sampling media, and analytical technique for each component sampled are all in Table I.

Long-term area samples for NO_2 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.

In addition to the area samples, long-term (full-shift) personal breathing-zone air samples were collected, to quantitate the time-weighted average exposures of some of the dock workers to particulate-borne elemental (and organic) carbon. These were collected by attaching a pump-and-filter personal sampler to each of those workers. These elemental carbon measurements represent the use of the approximate index of overall exposure previously established by the area samples. Again, the sampling and analytical techniques used are provided in Table I. All long-term air samples were submitted for analysis to the NIOSH analytical laboratory or to a NIOSH contract analytical laboratory.

B. Medical

A self-administered questionnaire was distributed to the entire group of 115 workers present on the 3 shifts which occurred during the visit (the day and swing shifts on March 23 and the night shift on March 24). Among this group, 81 employees were dock workers and 34 were yard workers. The questionnaire addressed specific symptoms as well as certain demographic, medical, smoking, and work history information. Specific questions were asked regarding the presence of several symptoms which occurred during the past month, and whether or not they improved, worsened, or remained unchanged at work. Other questions pertained to whether or not symptoms were present since the beginning of the shift on the day the questionnaire was completed.

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 [2]. 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) [2]. It has been estimated that as many as 18,000 different substances from the combustion process can be adsorbed onto diesel exhaust particulates [2]. 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 [2].

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 studies in rats and mice confirm an association between cancer and exposure to whole diesel exhaust [3]. The lung is the primary site identified with the carcinogenic or tumorigenic responses following inhalation exposure. Limited epidemiologic evidence suggests an association between occupational exposure to diesel engine emissions and lung cancer [3]. The consistency of current toxicological and epidemiological evidence suggests that a potential occupational carcinogenic hazard exists from human exposure to diesel exhaust [2]. Tumor induction is associated with diesel exhaust particulates, and limited evidence suggests that the gaseous fraction of diesel exhaust may be carcinogenic as well [2].

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) [4], the ACGIH TLVs [5], and the NIOSH Recommended Exposure Limits (NIOSH RELs) [6] relevant to as many as possible of the substances, or classes of substances, for which air samples were collected in this evaluation. In addition to these criteria for individual substances, NIOSH recommends that whole diesel exhaust be regarded as a potential occupational carcinogen, and that exposures to it be reduced to the lowest feasible limits [2]. No safe level has been demonstrated for a carcinogen.

V. RESULTS AND DISCUSSION

A. Environmental

The inspection of the terminal facilities and activities revealed that the dock has five 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 only a small number of the 144 doors in the facility are typically left unoccupied during the night shifts when operating rates are heavy, although the exact number and pattern of unoccupied doors is unpredictable for a particular shift (since the use or non-use of a particular bay door is dictated by the amount and destination of the cargo). No specific provision for make-up air for the roof exhaust fans is present; rather, air will enter through the previously noted openings. No other air handling or conditioning systems are used in the dock area.

During the night shift at the time of the air sampling, 16 diesel-powered forklift trucks were in use. Four were older models, which are suspected to be emitters of relatively high levels of pollutants. The operations that night were described as being typical of a moderate-to-heavy workload. However, it was noted that at certain times in the past, noticably heavier fume concentrations had been experienced. As many as 15 doors (but often fewer) were left unoccupied at times during the night shift, and for a time, around 4 a.m., several doors in the vicinity of the sampling location near door #71 were left unoccupied. Therefore, airborne levels of diesel-engine exhaust emissions may have been slighly reduced below normal by the number and pattern of doors left open; this statement and the some of the above information supporting it are based on comments made by union and management personnel. Measured temperatures in the dock area ranged between 52 and 55°F during the survey, and measured relative humidities ranged between 81 and 90%.

The measured concentrations of each of the four 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, the levels of CO_2 detected are similar to normal atmospheric levels. 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 air samples are shown in Tables IV, V, and VI. Among the long-term area air-sampling results, as with the short-term area sampling results, no trend indicating that concentrations of most of these contaminants were greater at one area sampling location than at the other was apparent. The results for formaldehyde, H_2SO_4, and NO_2 (Table IV) and for the individual PAHs benzo[a]pyrene, naphthalene, and chrysene (Table V) are well below all relevant evaluation criteria. The results in Table IV for particulate sulfate (SO_4^{-2}) represent the presence of total sulfate, in both ionic and molecular forms (including H_2SO_4), impregnated upon airborne particulates. Since any other sulfates present are expected to be no more irritating than H_2SO_4, these results may be grouped with the corresponding H_2SO_4 results, and the measured total airborne concentrations are still well below the relevant evaluation criteria (for H_2SO_4). The results of the samples for SO_2 were rendered invalid by an unidentified sampling and/or analysis problem (Table IV). However, in a previous evaluation of a similar facility performed by the NIOSH investigators [7], similar very low levels of H_2SO_4 and particulate sulfate were accompanied by very low levels of SO_2. No additional volatile organic compounds (aliphatic or aromatic hydrocarbons) were detected (Table IV). (This does not include vapor-phase PAHs [Table V, PAH samples, analyses of sorbent tubes].)

Although airborne (total and respirable) particulate results (Table V) are well below the evaluation criteria for "nuisance" particulate listed in Table II, these criteria are generally applied to biologically "inert" materials. Particulates emitted from diesel engines bear chemical substances of toxicological significance. Therefore, the nuisance particulate criteria are not adequate in this case. Also, the sub-micron fraction (less than 1 micron [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 um in size [2]) compared with other sources, such as re-entrained or agglomerated exhaust-emission particles or other sources of dust. Unfortunately, unidentified sampling and/or analysis problems rendered the results of the samples for the sub-micron fraction invalid. Nevertheless, it can be deduced from comparison of the results of the samples for total particulates and the respirable fraction (which, due to the sampling techniques and devices used, excludes particles greater than 10 um in size [1]) that larger particles (greater than 10 um), presumably from sources other than direct emissions, appeared to predominate in this facility 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).

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 applicable to 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. However, the result for sample ZF-3 (Table V), at 0.06 mg/m^3, exceeds one-half of the NIOSH REL of 0.1 mg/m^3.

The results of the samples for elemental carbon in Table VI are not comparable with any published evaluation criteria. The samples were collected for use as an index of overall exposure to diesel-engine exhaust emissions, based upon the fact that the particulate phase of the emissions is composed of elemental-carbon cores onto which other materials are adsorbed [2] (as discussed above in Section IV). Using this parameter as an index of overall exposure requires the assumption that, in a given facility or area during a given time, the time-weighted average concentrations of the materials adsorbed onto the elemental-carbon cores will correlate with the time-weighted average concentration of elemental carbon when side-by-side samples are compared. It may also be assumed that a correlation likely exists with the vapor-phase components of diesel-engine exhaust emissions, since the aerodynamic behavior (in terms of suspension in the air and movement with the flow of an air stream) of a vapor can be closely approximated by fume-like aerosols such as the small diesel-exhaust particulates. The strengths of these correlations are under investigation by NIOSH researchers, but as yet are undetermined. The area samples for elemental carbon were collected side-by-side with the area monitors for the other measured components of the emissions to provide a basis for comparison of the elemental carbon levels to the levels of the other components. This was done to establish the correlation used with the personal samples (discussed below).

Total organic carbon may also be determined from the samples collected for elemental carbon; the results of these analyses were compiled and are also reported in Table VI. Although these results are not comparable with any existing evaluation criteria, they can be used to assess the usefulness of the elemental carbon measurements for the evaluation of exposures to diesel-engine exhaust emissions; this was done by determining the proportion of the total carbon (both elemental and organic) that is attributable to elemental carbon. Elemental carbon may account for between 35 and 85% of the total mass in diesel-exhaust particulates [2, 8], but usually accounts for between 60 and 80%, with organics accounting for the other 20 to 40% [8]. The area sampling results established a baseline of 60% (as a mean; the proportions for the individual samples range from 58 to 61%) elemental carbon in this facility during the survey, confirming that the detected elemental carbon is very likely associated with the diesel-engine exhaust emissions alone.

The results of the long-term personal air samples for elemental carbon (Table VI) indicate that personal exposure levels ranged from less than 80%, to more than 220%, of the mean area concentration of 42 ug/m^3 (the four area sample results ranged from 40 to 44 ug/m^3); 8 of 10 personal exposure levels exceeded the mean area concentration. Apparent among these results is a slight trend indicating that the exposures were greater among employees working in zone #2 of the dock, and perhaps in zone #1, than in zone #3. However, this is not consistent with the fact that trends by location are not otherwise seen in this facility. Given the small number of samples, it is plausible that this is not a trend related to the employees' locations (such as one caused by physical characteristics of the facility), but rather is due to the random distribution of the workload among individuals during the night of the survey.

The personal samples (Table VI) were also analyzed for total organic carbon, primarily to help NIOSH investigators assess the usefulness of the elemental carbon measurement for the evaluation of exposures to diesel-engine exhaust emissions by again determining the proportion of the total carbon that is attributable to elemental carbon. The elemental portion of total carbon for two personal samples, COP.7 and COP.10, is very similar to the baseline of 60% established by the area sampling results, at 59% and 64%, respectively. However, for the remaining eight personal samples, the elemental portion of the total carbon is less than 50%, and for five of those is less than 40%. In other words, the total organic portion of the total carbon is at the expected value in two, and elevated in eight, of ten personal samples. This indicates personal exposures to carbon-containing emissions, from a source other than diesel engines and with a different proportion of elemental carbon within the total carbon, which are a potential interference with the use of elemental carbon as an index of exposures to diesel-engine exhaust emissions. These additional emissions interfere in this fashion only if they add substantial quantities of elemental carbon to the air compared with that released by the diesel engines. Identification of the additional source of emissions and the nature of these emissions (i.e., their proportional content of elemental carbon) is necessary to determine this.

Based on the information in the next paragraph, it is very likely that the higher-than-expected proportions of total organic carbon among the personal samples are attributable entirely to exposure to cigarette smoke. Although the exposure of the sampled workers (and their samplers) to cigarette smoke greatly increased the detected levels of total organic carbon, it likely had little effect upon the measured exposures to elemental carbon because cigarette smoke contains only 1 to 1.5% elemental carbon [9]. Therefore, it is still very likely that the exposures to elemental carbon are associated with the exposures to diesel-engine exhaust emissions alone.

The following evidence indicates that the higher-than-expected proportions of total organic carbon among the personal samples are attributable to exposure to cigarette smoke: (1) the only plausible additional exposure to the workers not found in the area monitoring locations is cigarette smoke; (2) four workers among the ten who wore samplers were known to have smoked during the shift (based upon the investigators' observations, and statements by the individuals), and others may also have smoked; and, (3) most workers spent some time in a break room that was observed to be smoky from cigarette smoke. Furthermore, the top three greatest and sixth greatest exposures to total organic carbon (represented by samples COP.8, COP.1, COP.6, and COP.2, respectively) were those of the four "known" smokers, and the two greatest proportions of total organic carbon in the total carbon (or, the smallest of elemental carbon, at 20 and 32%, respectively) were also found in two of those four samples (COP.1, and COP.8, respectively). All four of those samples had proportions of total organic carbon greater than 50% (i.e., proportions of elemental carbon of less than 50%).

The environmental evaluation criteria listed in Table II are directly applicable to personal exposure levels, but the sampling for the individual components of diesel-engine exhaust emissions (except for the elemental [and total organic] carbon sampling) conducted during this HHE measured general-area levels. The elemental carbon sampling provides evidence that most personal exposures to the individual components were greater than the area levels, in the most extreme case possibly more than twice as great (based upon the data discussed above, showing 8 of 10 personal exposures to elemental carbon exceeding the mean area concentration, including one at 220% of that mean). This may be due to such effects as the operation of forklift trucks inside trailers, and the closer proximity of the sources (exhaust tailpipes) to the workers than to the area monitors. Furthermore, the measured levels of the various exhaust-emission components represent those found under the conditions on the night of the survey, and may differ at other times. They may have been slighly reduced below usual levels by the number and pattern of doors left open during the sampling (as discussed earlier in this section).

Despite the fact that personal exposures to the individual components of diesel-engine exhaust emissions likely exceed the measured area concentrations found in Tables III, IV, V, and VI, it is unlikely that they ever increase sufficiently to cause overexposures to any individual component (except for the solvent-extractable fraction of particulate) compared to current occupational exposure criteria. This is because measured levels of all other individual components were well below relevant criteria, with only formaldehyde and H_2SO_4 levels (at 0.002 ppm in samples HCHO-1 and -2, and 0.11 mg/m^3 in sample S-1, respectively [see Table IV]) falling within even an order of magnitude of an evaluation criterion (NIOSH TWA REL of 0.016 ppm, and all three TWAs of 1 mg/m^3, respectively). However, the result for solvent-extractables sample ZF-3 (Table V), at 0.06 mg/m^3, exceeds one-half of the NIOSH REL of 0.1 mg/m^3 for cyclohexane-solubles, and, based upon the elemental carbon exposure index, the personal exposures likely ranged as high as about 0.13 mg/m^3, exceeding this REL.

The solvent-extractable 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 due to the previously discussed lack of direct comparability between the evaluation criteria and the results, 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 levels discussed above (as described previously).

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 H_2SO_4 levels were measured within an order of magnitude of such a criterion (as described in the previous paragraph). There is no indication that the <u>measured</u> irritants, in the concentrations measured or likely to be encountered in the facility, cause appreciable irritant effects in a substantial proportion of workers. This statement includes any single one, or any combination, of the measured irritants. It excludes any additional irritants which may be, or may have been, present but were not detected during the survey with the techniques used.

As previously mentioned in the Introduction section of this report, the union which requested this HHE asked NIOSH to evaluate exposures of the dock workers to diesel-engine exhaust emissions, so the environmental portion of this evaluation focused on these workers' exposures. Air sampling to assess the yard workers' exposures was not conducted. However, in the judgement of the investigators, the yard workers' exposures to diesel-engine exhaust emissions were lower than the dock workers' exposures at the time of the survey, and are normally lower at other times also. This is based upon location of the yard workers' jobs compared to those of the dock workers (outside the building versus inside, respectively) and the normally intermittent nature of their exposures (except during cold weather when the trucks in the yard are left idling).

B. Medical

The participants in the survey were all male. The ethnic composition of the group included 113 whites (non-hispanic) and 2 workers of hispanic origin. These workers ranged in age from 25 to 58 years old, with the average age being 39.2 years.

Dock workers, designated as the higher-exposure group, were compared with respect to demographics and symptomatology with the yard workers, designated the lower-exposure group. These exposure definitions are based upon the discussion in the previous paragraph. The yard workers were slightly older (average age = 41.8 years) than dock workers (average age = 38.2 years). Dock workers had been employed at the company an average of 10.9 years as compared with an average of 8 years for yard workers. The groups were comparable with respect to smoking history. Among dock workers 63.8% were smokers as compared with 67.7% of yard workers. Tables VII through X depict the comparisons with respect to symptomatology between these two groups of workers at this terminal.

Table VII, "Work-related Symptoms in the Preceding Month," lists the symptoms related by workers as occurring during the month prior to completing the questionnaire. Only symptoms which became worse while at work during this time period were considered to be work related. As shown in the Table, the symptom most frequently reported by the 81 dock workers was cough with sputum production, by 39 workers (48.2%), as compared with only 2 of the 34 yard workers (5.9%). In decreasing order of frequency, the other reported symptoms were: eye irritation, sore throat, headache, dyspnea (shortness of breath), dry cough, tearing of eyes, nasal discharge (runny nose), nasal congestion (stopped up nose), wheezing, and hoarseness. Frequency, and relative risk (RR) along with the 95% confidence interval (CI), are reported in the Table for each symptom. Those values listed under the column entitled "RR" provide a measure of the strength of association between work location and each reported symptom. The only important exposure difference between dock and yard workers was judged to be in their levels of exposure to diesel-engine exhaust emissions, as previously discussed. The values listed under the column heading "95%CI%" give an indication of the reliability of each estimate.

Table VIII lists the current symptoms reported by dock and yard workers on the day the questionnaire was administered. Eye irritation was the most frequently reported symptom among both groups of workers. This symptom was noted by 54(66.7%) dock workers as compared with 7(20.6%) yard workers. Other frequently reported symptoms among dock workers were productive cough, sore throat, headache, dyspnea (shortness of breath), and dry cough. Less than 35% of dock workers reported experiencing nasal congestion, eye tearing, runny nose, wheezing, or hoarseness, on that day. As a group, 6(17.7%) or fewer yard workers noted any of the remaining symptoms.

In Table IX, a comparison of symptoms experienced during the preceding month was made among the 27 dock workers on each shift. Shift 1 occurred from 12 midnight to 7 a.m., shift 2 from 7 a.m. to 3 p.m., and shift 3 from 3 p.m. to 12 midnight. Examination of this data reveals that shifts 1 and 3 reported a higher frequency of symptoms as compared with shift 2, in which fewer workers reported experiencing symptoms. Productive cough and eye irritation were noted by more than one-half of all workers on shifts 1 and 3, and along with headache were also the most common symptoms reported by workers on shift 2. A similar pattern is seen in Table X, which describes current symptoms among dock workers according to shift. Eye irritation was the number one symptom reported by all groups except for shift 2, in which productive cough was most frequently noted.

The fact that eye irritation was the most prevalent acute symptom reported by this population of workers supports the evidence documented in scientific literature that diesel exhaust emissions cause acute eye irritation in humans. It is also of importance that respiratory symptoms, as well as symptoms of mucous membrane irritation, were more prevalent among dock workers than yard workers. Based upon these findings, the NIOSH investigators have concluded that, despite the low measured airborne concentrations of irritants, workers reported acute irritative health effects consistent with the symptoms of exposure to whole diesel exhaust.

The exact cause of the acute effects is uncertain due to the absence of exposures in excess of the relevant criteria. As described previously, few irritants were measured at concentrations within even an order of magnitude of an 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.

The NIOSH investigators have also concluded that there exists at this facility the potential for long-term health effects, primarily the potential carcinogenic risk described previously. (Few conclusions can be drawn from available studies of chronic pulmonary and systemic effects.) This conclusion is supported by several items previously discussed relating to worker exposures at this facility. The first of these is that the material adsorbed onto diesel exhaust particulates, to which the employees at this facility are exposed, includes such compounds as PAHs, among which are a number of known mutagens and carcinogens. In fact, two individual PAHs were detected (at very low levels) in this work environment (Table V). Furthermore, one sample for benzene-extractable fraction of particulate, despite the inherent problems with interpretations and the assumptions that must be used, does provide evidence of possibly excessive exposures to these materials; the main toxicological concern regarding them is their carcinogenic potential, and no safe level has been demonstrated for a carcinogen.

Based upon reported acute irritative health effects consistent with exposure to diesel exhaust, and the fact that NIOSH recommends that whole diesel exhaust be regarded as a potential occupational carcinogen, the NIOSH investigators have concluded that a potential health hazard exists at this facility.

VI. RECOMMENDATIONS

Because a potential health hazard exists at this facility, measures to reduce exposures should be instituted. Specifically, exposures should be reduced to the lowest feasible limits in accordance with NIOSH recommendations [2], previously discussed in Section IV. These state, "NIOSH recommends that whole diesel exhaust be regarded as a potential occupational carcinogen in conformance with the OSHA Cancer Policy (29 CFR 1990)...The excess cancer risk for workers exposed to diesel exhaust has not yet been quantified, but the probability of developing cancer should be decreased by minimizing exposure...(E)mployers should assess the conditions under which workers may be exposed to diesel exhaust

and reduce exposures to the lowest feasible limits." The following are several specific measures to reduce exposures.

1. Serious consideration to phasing out the diesel-powered forklift trucks in favor of forklifts powered by other, less polluting, fuels should be made. Extreme caution is needed when making such changes to be sure that emissions from the replacement units do not create a new hazard, such as high CO exposures due to the relatively high CO emissions from non-diesel internal-combustion engines.

2. Whenever diesel-powered forklift trucks are left unattended for more than the briefest of periods, their engines should be shut off. Also, older-model diesel forklifts should be selected for use only if needed when all newer-model units are in use.

3. Engine and fuel modifications can reduce the rates of emission of toxic substances from diesel engines. The assistance of forklift manufacturer representatives should be sought to decrease the rate of exhaust emissions from the diesel-powered forklift trucks (particularly the older models and those considered to be excessive emitters). Any forklift trucks not operating properly, as indicated by visibly smoky exhaust emissions or other irregularities, should be immediately removed from service.

4. The performance of the roof exhaust fans should be evaluated by a qualified ventilation engineer to be certain that they are operating as designed. If they are not, then repairs should be made. If the fans are operating as designed, then additional ventilation should be provided to reduce exposure levels. After repairs and/or additions are made, the effectiveness of the ventilation should be reassessed. One indicator of effectiveness would be the reduction of airborne concentrations of pollutants which are components of diesel-engine exhaust emissions, and thus the subsequent measurement of these concentrations should be performed.

5. Provision of proper washing, clothes-changing, and clothes-laundering facilities is necessary to prevent unnecessary off-site exposure to diesel-engine exhaust particulates ("soot"). Such facilities should be provided and used.

As a general recommendation, 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 both union and management representation. Workers assigned to work in areas where diesel-powered equipment is operated should be informed about the workplace hazards.

VII. REFERENCES

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9. Zaebst, D.D. Presentation on elemental carbon and diesel exhaust. Presented at: the American Industrial Hygiene Conference, San Francisco, California, 1988.

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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. 722
4. OSHA, Region V
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.
Peru, Illinois
HETA 88-077
24 March 1988

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 3m<u>M</u> sodium bicarbonate ($NaHCO_3$) and 2.4 m<u>M</u> 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 3m<u>M</u> $NaHCO_3$ and 2.4 m<u>M</u> 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

TABLE I (CONTINUED...)

Contaminant	NIOSH Method Number [1]	Collection Medium	Volumetric Air Flow Rate (L/min) Used	Desorbing Solvent or Solution	Type of Analysis Used
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	3.5	Benzene	Gravimetric
Acetonitrile-soluble fraction of particulate	5023	Filter - PTFE-membrane	3.5	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, and organic carbon	****	Filter - quartz-fiber**	4.0		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.

TABLE II
Evaluation Criteria
Consolidated Freightways, Inc.
Peru, Illinois
HETA 88-077
24 March 1988

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	-
	(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.
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 material 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., Peru, Illinois
HETA 88-077
24 March 1988

LOCATION	ANALYTE	TIME, a.m.	CONCENTRATION, ppm	NOTES
Near Door 134	NO_2	1:10	Trace (<0.5)	
"	NO_x	1:13	0.3	$NO + NO_2$
"	CO	1:20	ND (<<0.5)	
"	CO_2	1:22	400	
Near Door 71	NO_2	1:32	Trace (<0.5)	
"	NO_x	1:33	0.3	$NO + NO_2$
"	CO	1:36	ND (<<0.5)	
"	CO_2	1:40	300	
Near Door 134	NO_2	6:02	ND (<<0.5)	
"	NO_x	6:06	Trace (<0.5)	$NO + NO_2$
"	CO	6:09	ND (<<0.5)	
"	CO_2	6:15	200	
Near Door 71	NO_2	6:18	ND (<<0.5)	
"	NO_x	6:20	0.2	$NO + NO_2$
"	CO	6:26	ND (<<0.5)	
"	CO_2	6:30	200	

ND None detected

TABLE IV
Results of Long-term Area Air Sampling for 6 Substances
Consolidated Freightways, Inc.
Peru, Illinois
HETA 88-077
24 March 1988

Location:	Near door 71					Near door 134				
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	12:52	6:31	320	0.002 ppm**	HCHO-2	12:46	6:26	320	0.002 ppm**
	HCHO-6	4:09	6:30	148	<0.003 ppm*	HCHO-5	4:07	6:26	130	<0.004 ppm
Hydrocarbons, aliphatic and aromatic	CT-1	12:52	7:26	79	ND	CT-2	12:46	7:27	80	ND
Particulate Sulfate Sulfur Dioxide	AA-1 SO2-1	12:52	7:26	650	0.009 mg/m^3** @@	AA-2 SO2-2	12:46	7:27	682	0.009 mg/m^3** @@
Particulate Sulfate Sulfuric Acid	S-2	12:52	7:26	180	<0.02 mg/m^3 0.04 mg/m^3**	S-1	12:46	7:27	180	<0.02 mg/m^3 0.11 mg/m^3
Nitrogen Dioxide	NO2-2	12:52	7:34	NA@	0.071 ppm	NO2-1	12:46	7:30	NA@	0.021 ppm

* 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
ND None detected
@ 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., Peru, Illinois
HETA 88-077
24 March 1988

Location:	Near door 71					Near door 134				
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
Total Particulates	FW 900	12:52	7:26	870	0.07	FW 1747	12:46	7:27	880	0.08
Respirable Particulates	FW 1010	12:52	7:26	670	0.04	FW 1743	12:46	7:27	680	0.01
Sub-micron Particulates	FW 884	12:52	7:26	830	@@	FW 1006	12:46	7:27	920	@@
Benzene-soluble Fraction of Particulates	ZF-1	12:52	7:26	1400	<0.04*	ZF-3	12:46	7:27	1400	0.06
Acetonitrile-soluble Fraction of Particulates	ZF-4	12:52	7:26	1400	<0.04	ZF-2	12:46	7:27	1400	<0.04

Polynuclear Aromatic Hydrocarbons (PAHs):

Extracting Solvent/ Analysis Method:	Benzene / GC/FID@	Acetonitrile / HPLC,Fl/UV Dtn#	Benzene / GC/FID	Acetonitrile / HPLC, Fl/UV Dtn
Filter/Tube Number:	ZF-6 / PAH-6	ZF-5 / PAH-5	ZF-8 / PAH-8	ZF-7 / PAH-7
Time Start/Stop, a.m.:	12:52 / 6:59	12:52 / 6:59	12:46 / 6:52	12:46 / 6:52
Sample Volume, L:	770	760	770	770

	Mass, ug		Concentration,		Mass, ng		Concentration,		Mass, ug		Concentration,		Mass, ng		Concentration,	
	from filter	from tube	total	ug/m^3	from filter	from tube	total	ug/m^3	from filter	from tube	total	ug/m^3	from filter	from tube	total	ug/m^3
Naphthalene	<0.5	<0.5	<1.0	<1.3##	NA+	NA	NA	NA	<0.5	<0.5	<1.0	<1.3##	NA	NA	NA	NA
Acenaphthylene	<0.3	<0.3	<0.6	<0.8	NA	NA	NA	NA	<0.3	<0.3	<0.6	<0.8	NA	NA	NA	NA
Acenaphthene	<0.3	<0.3	<0.6	<0.8	<100	<100	<200	<0.26	<0.3	<0.3	<0.6	<0.8	<100	<100	<200	<0.26
Fluorene	<0.3	<0.3	<0.6	<0.8	NA	NA	NA	NA	<0.3	<0.3	<0.6	<0.8	NA	NA	NA	NA
Phenanthrene	<0.3	<0.3	<0.6	<0.8	<30	<50	<80	<0.1	<0.3	<0.3	<0.6	<0.8	<30	<50	<80	<0.1
Anthracene	<0.3	<0.3	<0.6	<0.8	<30	<30	<60	<0.08	<0.3	<0.3	<0.6	<0.8	<30	<30	<60	<0.08
Fluoranthene	<0.3	<0.3	<0.6	<0.8	<30	<30	<60	<0.08	<0.3	<0.3	<0.6	<0.8	<30	<30	<60	<0.08
Pyrene	<0.3	<0.3	<0.6	<0.8	<30	<50	<80	<0.1	<0.3	<0.3	<0.6	<0.8	<30	<50	<80	<0.1
Benz(a)anthracene	<0.3	<0.3	<0.6	<0.8	<30	<30	<60	<0.08	<0.3	<0.3	<0.6	<0.8	<30	<30	<60	<0.08
Chrysene	<0.3	0.3**	0.3**	0.4**	<30	<30	<60	<0.08	<0.3	<0.3	<0.6	<0.8	<30	<30	<60	<0.08
Benzo(b)fluoranthene	<0.3	<0.3	<0.6	<0.8	<30	<30	<60	<0.08	<0.3	<0.3	<0.6	<0.8	<30	<30	<60	<0.08
Benzo(k)fluoranthene	<0.3	<0.6	<0.9	<1	<30	<30	<60	<0.08	<0.3	<0.6	<0.9	<1	<30	<30	<60	<0.08
Benzo(e)pyrene	<0.3	<0.3	<0.6	<0.8	<30	<30	<60	<0.08	<0.3	<0.3	<0.6	<0.8	<30	<30	<60	<0.08
Benzo(a)pyrene	<0.3	<0.3	<0.6	<0.8	<30	<30	<60	<0.08	<0.3	<0.3	<0.6	<0.8	<30	<30	<60	<0.08
Indeno(1,2,3-c,d)pyrene	<0.5	<0.5	<1.0	<1.3	<50	<50	<100	<0.13	<0.5	<0.5	<1.0	<1.3	<50	<50	<100	<0.13
Dibenz(a,h)anthracene	<0.3	0.5**	0.5**	0.6**	<50	<50	<100	<0.13	<0.3	<0.5	<0.8	<1	<50	<50	<100	<0.13
Benzo(g,h,i)perylene	<0.3	<0.3	<0.6	<0.8	<50	<50	<100	<0.13	<0.3	<0.3	<0.6	<0.8	<50	<50	<100	<0.13

* 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
\+ NA indicates "not analyzed"
@ Gas chromatography with flame-ionization detection
\# High-performance liquid chromatography with fluorescence/ultraviolet detection
\## <0.00025 ppm
@@ Unidentified sampling and/or analysis problem; result invalid

TABLE VI

Results of Long-term Air Sampling for Sub-micron Particulate-bome Elemental Carbon and Organic Carbon
Consolidated Freightways, Inc.
Peru, Illinois
HETA 88-077
24 March 1988

Type/Location	Sample Number	Time, a.m. Start	Time, a.m. Stop	Volumetric Flowrate (L/min)	Sample Volume (L)	Concentration (ug/m^3) Elemental Carbon	Concentration (ug/m^3) Organic Carbon
Personal/Towmotor, in zone #3	COP.1	12:32	7:39	4.0	1700	33	130
	COP.2	12:30	7:46	4.0	1700	50	76
	COP.3	12:29	7:43	4.0	1700	40	52
	COP.4	12:27	5:33	4.0	1200	44	87
Personal/Towmotor, in zone #2	COP.5	12:23	7:32	4.0	1700	59	87
	COP.6	12:18	7:21	4.1	1700	94	96
	COP.8	12:20	6:53	4.0	1600	77	160
Personal/Towmotor, in zone #1	COP.7	12:10	7:27	4.0	1700	69	47
	COP.9	12:07	7:26	4.0	1700	65	68
	COP.10	1:48	7:49	4.0	1500	54	31
Area/Near door #71	COP.11	12:43	7:30	4.1	1700	40	26
	COP.12	12:43	7:30	3.9	1600	43	30
Area/Near door #134	COP.13	12:47	7:30	4.0	1600	44	28
	COP.14	12:47	7:30	4.0	1600	43	31

TABLE VII

Analysis of Questionnaire-response Results:
Work-related Symptoms in the Preceding Month
Consolidated Freightways, Inc.
Peru, Illinois
HETA 88-077
24 March 1988

Symptoms	Dock 81 workers	Yard 34 workers	RR*	95%CI*
Headache	29(35.8%)	3(8.8%)	4.1	1.59,10.34
Eye Irritation	36(44.4%)	7(20.6%)	2.2	1.15,4.04
Tearing of eyes	24(29.6%)	5(14.7%)	2.0	0.89,4.57
Runny Nose	23(28.4%)	5(14.7%)	1.9	0.84,4.43
Stopped Up Nose	20(24.7%)	3(8.8%)	2.8	0.99,7.94
Sore Throat	31(38.3%)	4(11.9%)	3.3	1.43,7.41
Hoarseness	15(18.5%)	1(2.9%)	6.3	1.22,32.6
Dry Cough	25(30.9)	1(2.9%)	10.5	2.55,43.27
Cough + Phlegm	39(48.2%)	2(5.9%)	8.2	3.14,21.34
Wheezing	16(19.8%)	2(5.9%)	3.4	0.94,12.03
Dyspnea**	29(35.8%)	1(2.9%)	12.2	3.18,46.65

* RR = relative risk (prevalence ratio); CI = confidence interval
** shortness of breath

TABLE VIII

Analysis of Questionnaire-response Results:
Symptoms Present on the Day of Interview
Consolidated Freightways, Inc.
Peru, Illinois
HETA 88-077
24 March 1988

Symptoms	Dock 81 workers	Yard 34 workers	RR*	95%CI*
Headache	42(53.2%)	4(11.8%)	4.52	2.19,9.31
Eye Irritation	54(66.7%)	7(20.6%)	3.24	1.94,5.40
Eye Tearing	27(33.8%)	4(11.8%)	2.87	1.21,6.78
Runny Nose	24(30.0%)	6(17.7%)	1.70	0.79,3.64
Stopped Up Nose	28(34.6%)	6(17.7%)	1.96	0.94,4.06
Sore Throat	46(57.5%)	2(5,9%)	9.77	4.06,23.54
Hoarseness	17(21.5%)	0	Undefined	Undefined
Dry Cough	35(43.9%)	5(14.7%)	2.97	1.45,6.12
Cough + Phlegm	49(62.0%)	6(17.7%)	3.51	1.98,6.23
Wheezing	22(27.9%)	4(11.8%)	2.37	0.95,5.88
Dyspnea	39(48.2%)	5(14.7%)	3.27	1.64,6.55

* RR = relative risk (prevalence ratio); CI = confidence interval

TABLE IX

Analysis of Questionnaire-response Results:
Symptoms Among Dock Workers in the Preceding Month,
According to Shift
Consolidated Freightways, Inc.
Peru, Illinois
HETA 88-077
24 March 1988

Symptoms	Shift 1 27 workers	Shift 2 27 workers	Shift 3 27workers
Headache	13(48.2%)	7(25.9%)	9(33.3%)
Eye Irritation	16(59.3%)	6(22.2%)	14(51.9%)
Tearing of eyes	15(55.6%)	2(7.4%)	7(25.9%)
Runny Nose	12(44.4%)	4(14.8%)	7(25.9%)
Stopped Up Nose	9(33.3%)	1(3.7%)	7(25.9%)
Sore Throat	13(48.6%)	6(22.2%)	12(44.4%)
Hoarseness	9(33.3%)	1(3.7%)	5(18.5%)
Dry Cough	13(48.6%)	2(3.4%)	10(37.0%)
Cough + Phlegm	17(63.0%)	8(29.6%)	14(51.9%)
Wheezing	8(29.6%)	1(3.7%)	7(25.9%)
Dyspnea	15(55.6%)	4(14.8%)	10(37.0%)

TABLE X

Analysis of Questionnaire-response Results:
Symptoms Present on the Day of Interview, Among Dock Workers,
According to Shift
Consolidated Freightways, Inc.
Peru, Illinois
HETA 88-077
24 March 1988

Symptoms	Shift 1 27 workers	Shift 2 27 workers	Shift 3 27 workers
Headache	17(63.0%)	10(38.4%)	15(57.7%)
Eye Irritation	20(74.1%)	13(48.2%)	21(77.8%)
Tearing of eyes	9(33.3%)	9(33.3%)	9(33.3%)
Runny Nose	9(33.3%)	9(33.3%)	6(23.0%)
Stopped Up Nose	7(25.9%)	10(37.0%)	11(40.7%)
Sore Throat	17(63.0%)	12(44.4%)	17(65.4%)
Hoarseness	4(15.4%)	5(18.5%)	8(30.8%)
Dry Cough	14(51.9%)	7(29.5%)	14(53.9%)
Cough + Phlegm	18(69.2%)	15(55.6%)	16(61.5%)
Wheezing	6(23.1%)	7(25.9%)	9(34.6%)
Dyspnea	14(51.9%)	12(44.4%)	13(48.4%)