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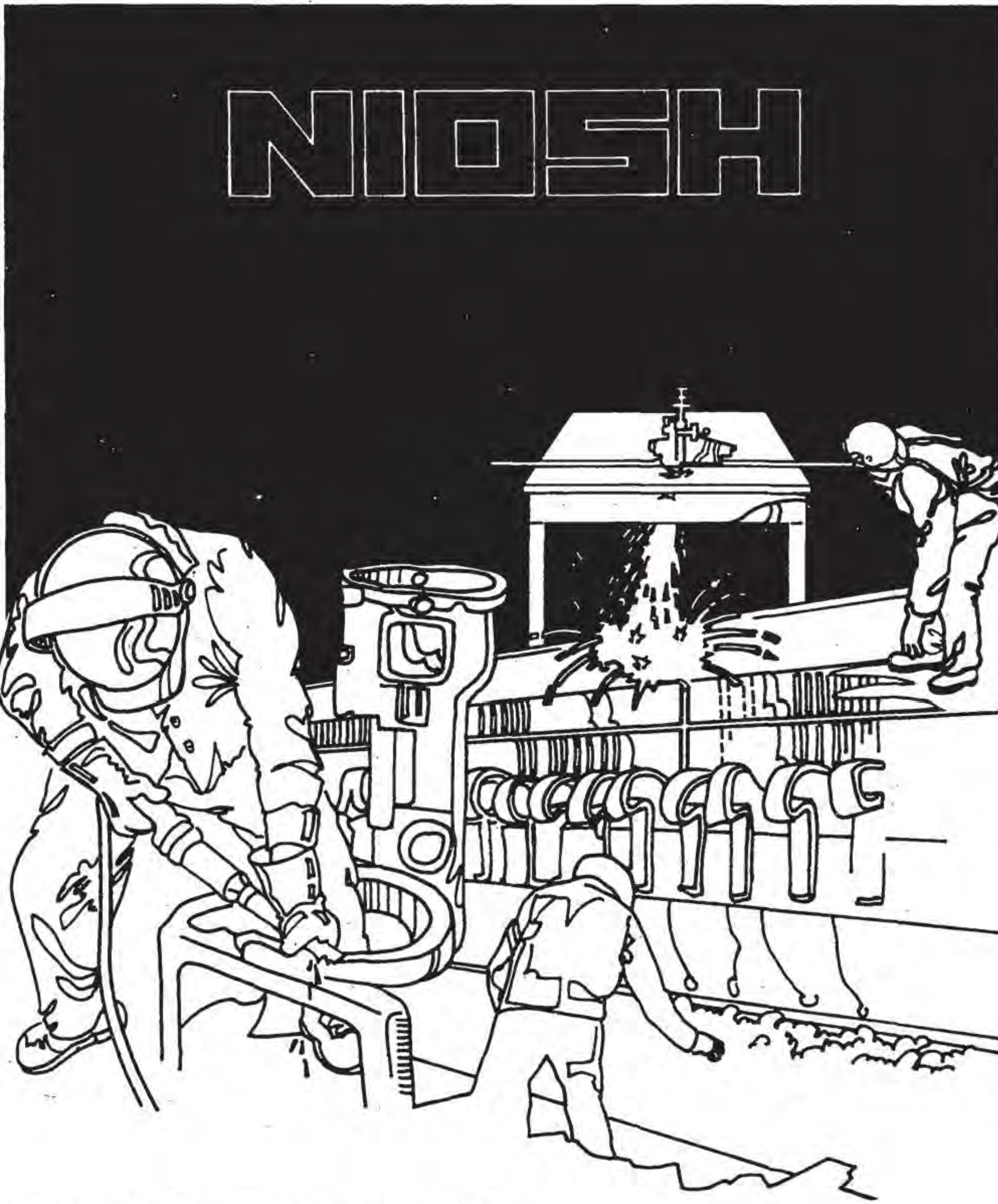

Health Hazard Evaluation Report

HETA 81-421-1251
GREAT LAKES CARBON CORP.
PORT ARTHUR, TEXAS

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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GREAT LAKES CARBON CORPORATION
PORT ARTHUR, TEXAS

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I. SUMMARY

On August 10, 1981, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation from the Oil, Chemical and Atomic Workers International Union and Local 4-23 at Great Lakes Carbon in Port Arthur, Texas. The union requested that NIOSH evaluate respiratory function and reported respiratory disease among workers exposed to petroleum coke dust at this facility.

To determine if respiratory problems existed among current employees and if these problems were related to coke dust exposure, NIOSH conducted site visits to the plant on November 5, 1981 and January 26-28, 1982. Ninety current employees (55%) participated in a medical investigation which included a respiratory questionnaire, pulmonary function tests and chest x-ray. Investigators obtained personal and area air samples for total and respirable dust, sulfates, sulfites, and polynuclear aromatic compounds (PNAs).

Levels of total airborne particulates ranged from 1.2 milligrams per cubic meter (mg/m^3) to 6.1 mg/m^3 with a mean of 3.4 mg/m^3. Airborne concentrations of respirable particulates ranged from 0.17 to 0.88 mg/m^3, with a mean of 0.44 mg/m^3. There is no OSHA standard for petroleum coke. These levels all were below the OSHA standard for total (nuisance) and respirable particulates. However, due to the PNA content of coke dust, it would not be appropriate to make a comparision with the nuisance dust standard.

The benzene-soluble fraction of the personal samples ranged from <70 ug/m^3 to 5100 ug/m^3 with an average level of 600 ug/m^3. Nine of the 18 samples exceeded the NIOSH recommended criteria of 100 ug/m^3 for coal tar pitch volatiles, and 8 of the 18 exceeded the OSHA standard of 200 ug/m^3. The purpose of these exposure criteria are to minimize worker exposure to carcinogenic PNA compounds. Fourteen PNAs were identified or quantified in personal breathing-zone air samples. Cumulative PNA concentrations ranged from 0.10 to 36 ug/m^3. No crystalline silica, sulfates or sulfites were detected.

The medical evaluation revealed abnormal pulmonary function test (PFT) results (1 restrictive, 2 obstructive, and 5 combination of both) among 9 (10%) current employees. PFT abnormalities were significantly related to dust exposure as measured by length of employment, age, and a history of working for five years or longer in the mobile equipment department. Chest x-rays showed no evidence of pneumoconiosis.

On the basis of the data collected in this evaluation, NIOSH determined that there was a hazard from overexposure to petroleum coke dusts containing PNA compounds. Although no pneumoconiosis was detected, the medical study did find evidence of occupationally related pulmonary function abnormalities. Recommendations to protect the health and safety of the workers are presented in Section VII of this report.

KEYWORDS: SIC 2999 (Products of Petroleum and Coal - Calcined Petroleum Coke), petroleum coke dust, polynuclear aromatics (PNAs), benzene-soluble fraction, pulmonary function, pneumoconiosis, chronic bronchitis, proportional mortality ratio.

II. INTRODUCTION

In August 1981, the Oil, Chemical, and Atomic Workers Internationl Union and Local 4-23 at Great Lakes Carbon (GLC) in Port Arthur, Texas, submitted a request to NIOSH to evaluate environmental conditions at the plant and possible adverse health effects among workers exposed to coke dust. The request stated that cases of anthracosis and anthrasilicosis, along with other respiratory diseases, had been reported among current and former workers.

The initial site visit was conducted on November 5, 1981. Although none of the four kilns normally in use were operational the day of NIOSH's visit, the walk-through survey indicated that dust exposure did exist at the plant and required further evaluation. An interim report describing this visit and plans for a follow-up study was distributed in January 1982.

On January 26-28, 1982, NIOSH conducted a follow-up study. A medical evaluation, consisting of a respiratory questionnaire, pulmonary function tests, and chest x-ray, was performed. Environmental air samples for total and respirable particulates, sulfates, sulfites, and polynuclear aromatic compounds (PNAs) were obtained.

III. BACKGROUND

The Great Lakes Carbon plant in Port Arthur, Texas, has been in operation since 1933, with the calcine operation beginning in 1935. The plant produces calcine which is used by the aluminum industry in the production of electrodes.

The raw material for the calcine operation, petroleum coke, is procurred by Great Lakes Carbon from several refineries and brought to Port Arthur by rail car. Each rail car is mechanically lifted and inverted in order to dump the coke onto a large grill used for separating the larger pieces. Much of the raw coke is then stored outdoors in large mounds until it is processed.

Heavy mobile equipment, such as front-end loaders, is frequently used for transporting coke to and from the storage mounds and to the conveyor systems that eventually feed into the kilns. Four large, horizontal, rotary kilns heat the coke to temperatures greater than 2000°F to form "calcine". The calcine is conveyed to silos to await transportation by ship or rail.

Airborne petroleum coke dust is generated on windy days, during the dumping of rail cars, the operating of mobile equipment, and the movement of open conveyors; thus all of the outdoor jobs at GLC involve potential exposure to petroleum coke dust. Calcine exposure is generally limited to one or two ship-loading workers per shift.

At the time of the survey, the plant employed approximately 165 employees. One-hundred-twenty of these were hourly employees, with the remainder being salaried personnel. Hourly employees working in the kiln department, mobile equipment, labor department, and operating department work all three shifts, while maintenance personnel work the day shift only.

Chest x-rays and pulmonary function tests have been performed by the company at the time of employment since May 1980. There are no periodic or termination medical exams. GLC has a death benefit policy which has been in effect since 1968.

A representative of the requesting union became concerned about the health of workers at GLC during the summer of 1980, when several cases of lung cancer, bronchitis, emphysema, and anthrasilicosis were reported among former and current employees. The union's medical staff began studying the respiratory status of workers at this time. Pulmonary function tests were administered to a group of workers with a greater than expected number of abnormal results reported. These records were obtained and reviewed by NIOSH.

IV. EVALUATION DESIGN AND METHODS

A. Environmental

NIOSH collected a total of 27 full-shift, personal breathing-zone and general area air samples on January 26-27, 1982, to evaluate worker exposure to: (1) total and respirable particulates which consisted primarily of petroleum coke dust, (2) crystalline silica, (3) sulfates and sulfites, and (4) polynuclear aromatic compounds (PNA's). The dust samples were collected on pre-weighed filters using calibrated personal sampling pumps drawing 1.7 liters of air per minute. Duplicate samples incorporating ten-millimeter cyclone preselectors were taken next to total dust samples in an attempt to compare respirable versus total dust concentrations.

The total dust samples also were analyzed for sulfates and sulfites according to NIOSH Method P&CAM No. 268. Those sampling trains included back-up filters impregnated with a potassium hydroxide-glycerol solution.

The respirable dust samples also were analyzed for crystalline silica according to NIOSH Method No. 259.

Sampling for airborne PNAs was performed by drawing air through a two-stage sampling unit consisting of glass fiber/silver membrane filters followed by an "XAD-2" tube containing a porous polymer sorbent. The benzene soluble fraction of the filter samples was determined and fourteen individual PNAs were quantitated by high resolution gas chromatography/mass spectrometry. The sorbent tubes were analyzed for phenanthrene.

Bulk samples of petroleum coke and calcine were collected, extracted for 24 hours, and analyzed for their PNA content. Both benzene and cyclohexane were used in order to compare their relative extraction efficiencies.

B. Medical

The medical study consisted of a questionnaire, pulmonary function test, and chest x-ray. The medical evaluation was offered to all plant employees. Salaried personnel were encouraged to participate, as many of them had previously worked in areas of production in the past. Ninety current employees participated, of whom 57 were hourly employees. Five retirees were tested, although the results of their tests were not included in the analyses.

A standardized medical questionnaire was designed and administered by NIOSH investigators. It consisted of a series of questions modeled after the British Medical Research Council's (BMRC) respiratory disease questionnaire for detecting symptoms of chronic bronchitis, shortness of breath, and wheezing. A brief medical history, a smoking history, and a detailed work history were included in the questionnaire. Demographic information was also obtained.

Workers were classified as having chronic bronchitis if they reported a productive cough on most days for three months a year, for two or more consecutive years.

Pulmonary function tests were administered to all participants and consisted of at least three properly performed forced exhalations to measure the forced vital capacity (FVC) and the one-second forced expiratory volume $(FEV)_1$. The NIOSH technicians utilized a Spirotech (Ohio Medical Products 822 dry rolling seal spirometer and a computer linkage which record the flow curves and analyzes them, as well as calculates expected values based on age, height, sex, and race[1,2]). The test was considered adequate if the FVC and the FEV_1 on the best two of at least three properly performed exhalations differed from each other by no more than 5%. The predicted normal values for age, height, and sex were based on Knudsons work.[1] The best FEV_1, FVC, and the ratio of FEV_1 to FVC (FEV_1/FVC) were used in subsequent calculations.

Pulmonary function tests were considered "normal" if the FEV_1 and FVC were each 80% or more of their respective predicted value and the FEV_1/FVC was 70% or greater. NIOSH test results were compared with those the union performed in 1981.

A chest x-ray (posterior-anterior view) was offered to all participants. NIOSH recommended x-rays for employees with 10 or more years of employment. 14"X 17" standard chest films were taken with a General Electric AMX-2 machine. Films were classified according to the International Labor Organization/University of

Cincinnati (ILO/UC) system for occupational lung diseases by two certified B readers (physicians certified in interpreting x-rays of occupational lung disease).

Statistical tests employed in the analysis of data included the chi-square test, the Fisher's exact test, the Wilcoxon ranked-sum test (non-parametric t-test), and the Spearman's correlation coefficient. Differences between the group of workers with and without abnormalities were considered to be significant at the $p<0.05$ level.

Although the purpose of this investigation was to evaluate the health status of current GLC employees, a list of death claims for the period 1968-1981 was obtained from the company during the initial site visit. This list was reviewed for lung cancer deaths. No attempt was made to collect mortality data on the remainder of the workforce (deaths prior to 1968) and/or on those who did not file death claims.

V. EVALUATION CRITERIA

A. 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 (TLV's), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's 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 only 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.

Listed below are the evaluation criteria referred to in this investigation:

	NIOSH Recommended Criteria	ACGIH TLV	OSHA Standard
Total Particulates	----	10 mg/m^3	15 mg/m^3
Respirable Particulates	----	5 mg/m^3	5 mg/m^3
Carbon Black	3.5 mg/m^3 or 0.1 mg/m^3 PNA content (cyclohexane extractable fraction)	3.5 mg/m^3	3.5 mg/m^3
Coal Tar Pitch Volatiles	0.1 mg/m^3 (cyclohexane solubles)	0.2 mg/m^3 (benzene solubles)	0.2 mg/m^3 (benzene solubles)

All values are time-weighted averages.
NIOSH criteria are based on a 10-hour workday.
ACGIH and OSHA levels are based on an 8-hour workday.

A. Coke Dust

Coke is the solid product resulting from the destructive distillation of coal (coal coke), or the heavy petroleum fraction resulting from the refinery of petroleum products (petroleum coke).

Coke consists primarily of pure carbon (generally 99%), with the balance consisting of such impurities as hydrogen or mineral impurities.[4] Coke usually contains little or no detectable silica.

Currently, there is no NIOSH criteria, OSHA standard, or ACGIH TLV for coke dust. Therefore, for the purpose of this study, environmental criteria for total (nuisance) particulates, respirable particulates, carbon black, and coal tar pitch volatives (CTPV) are referred to in evaluating occupational exposure to coke dust.

For most industrial purposes, carbon black and petroleum coke are substantially different materials, however, there are similarities, especially in their PNA content, that justify some comparisons when evaluating their potential health effects. The major chemical property that has been thoroughly investigated is their percentage of carbon which is usually at least 99% in both substances. The major physical difference between the two substances which relates to potential health effects is probably their particle size and adsorptive characteristics. Most carbon blacks generally consist of very fine particles with diameters less than 0.5 um.[5] In one recent study of petroleum refinery workers, the investigators found that petroleum coke dust from four refineries had particle diameters less than 8.3 um.[6] Particles less than 10 um are generally considered to be in the respirable size range. Thus, it appears that the PNA content of these and similiar materials is one of the most important constituents to be studied. In fact, both the NIOSH and ACGIH recommended standard for carbon black were primarily designed to minimize worker exposure to PNA compounds. The ACGIH TLV committee found considerable variation in the benzene extractable content among the different types of carbon black. For instance, channel black was found to contain very little material removable by hot benzene extraction, whereas furnace black had a 0.28% benzene extractable fraction. The committee concluded that "the 3.5 mg/m^3 TLV would keep the absorbed values of polycyclic aromatic hydrocarbons well below their limit of 0.2 mg/m^3.[7] The NIOSH approach to the recommended standard specifies that exposure to any type of carbon black should not exceed 3.5 mg/m^3 or 0.1 mg/m^3, measured as the cyclohexane extractable fraction.[5]

Table I compares the PNA content of petroleum coke and calcine samples taken from Great Lakes Carbon versus the PNA content of several varieties of carbon black.[8] The results show that petroleum coke contains greater amounts of PNA compounds than many of the carbon blacks. Therefore, the carbon black standard may be useful as a guide to controlling petroleum coke exposures but may not provide adequate protection.

It should be noted that considerable controversy arose from the development of the carbon black criteria that could have future relevance to other carbon products, including petroleum coke. Basically, the opponents of the current carbon black standard believe that the "alleged" carcinogenic potential of carbon black was based on incorrect analogies with various carcinogenic coal tar products. One of the major arguments is that PNA's are strongly adsorbed on commercial carbon black particles and cannot significantly be eluted by biological systems whereas many coal tar products often contain unadsorbed PNA molecules. Further negative evidence includes several epidemiologic studies of workers exposed to carbon black dust in North America and Western Europe which show no excess in mortality or morbidity due to cancer, heart disease, or respiratory disease. However, until there is better evidence for biological inavailibility of these PNA's, exposures to these materials must be handled cautiously.

B. <u>PNAs and Benzene or Cyclohexane Solubles</u>

PNAs are condensed ring aromatic hydrocarbons normally arising from the combustion of organic matter. They are commonly emitted into the air when coal tar, coal tar pitch, or their products are heated, but can result from burning the heavy petroleum fraction used in petroleum coke.[9] A number of PNAs, including benzo(a)pyrene and anthracene are carcinogenic (lung and skin). There are no federal standards pertaining to airborne concentrations of individual PNAs. In 1967, the ACGIH adopted a TLV of 0.2 mg/m^3 for CTPV, described as a "benzene-soluble" fraction, and listed certain carcinogenic components of CTPV. The TLV was established to minimize exposure to the listed substances believed to be carcinogens, viz, anthracene, BaP [benzo(a)pyrene], phenanthrene, acridine, chrysene, and pyrene. CTPV's are among the seven substances listed as "Human Carcinogens" in Appendix A of the current ACGIH TLV's. This group consists of "a substance, or substances, associated with industrial processes, recognized to have carcinogenic or cocarcinogenic potential with an assigned TLV". The TLV was promulgated as a federal standard under the Occupational Safety and Health Act of 1970 (29 CFR 1910.1000).[10] In 1972, the Federal Register (37:24749, November 21, 1972) contained an interpretative rule of the term "coal tar pitch volatiles": ". . . coal tar pitch volatiles include the fused polycyclic hydrocarbons which volatilize from the distillation residues of coal, petroleum, wood, and other organic matter". This has been reprinted as 29 CFR 1910.1002. The general philosophy behind this interpretation was that "all of these volatiles have the same basic composition and . . . present the same dangers to a person's health".[11]

In the development of the NIOSH recommended standard, it was concluded that CTPV's are carcinogenic and can increase the risk of lung and skin cancer in workers. Since no absolutely safe concentration can be established for a carcinogen, NIOSH recommended the exposure limit be the lowest concentration that can be reliably detected by the recommended method of environmental monitoring. At that time (September 1977) the lowest detectable concentration for CPTV's was 0.1 mg/m^3.

Although the benzene or cyclohexane extractable fraction offers an easier, less expensive method of analysis than PNA quantitation, there is no certainty that there is a correlation between the two. The analytical method for measuring the benzene-soluble fraction is not limited to PNAs but will include all other organic compounds collected on the filter and soluble in benzene.[6]

C. Respiratory Effects

Coke Dust

There are currently no published studies of the respiratory effects of work in the petroleum coke industry. However, there are several studies which provide documentation of pneumoconiosis related to carbon dust exposure which is indistinguishable from that seen in coalworkers.

A study by Watson et al (1959) gives an account of a clinical survey of 15 carbon electrode makers, of whom 4 suffered from complicated and 5 from simple pneumoconiosis. The authors concluded that carbon electrode makers may develop simple pneumoconiosis with focal emphysema, and a complicated form of the disease which are indistinguishable from the corresponding conditions in coalworkers.[13] In this study, the dust consisted of mainly coal and coke particles. Meiklejohn's (1957) study of workers employed in the manufacture and handling of carbon black suggests that the inhalation of nearly pure carbon over prolonged employment resulted in radiologic evidence of very early simple pneumoconiosis of the coalworkers' type but without clinical effects.[4] Both of these studies were based on radiological and/or pathological findings of pneumoconiosis. Okutani (1963) found (graphite) pneumoconiosis among 112 (43% of those examined) carbon electode makers exposed to average dust levels of 57.6 mg/m^3 in Japan.[14] A survey of respiratory disease in carbon black workers in the U.K. and the U.S.A. (Crosbie, 1976) showed no evidence of harmful effects from the inhalation of carbon dust.[15]

VI. RESULTS AND DISCUSSION

A. Environmental

Seven personal breathing-zone air samples for total particulates ranged from 1.2 to 6.1 milligrams per cubic meter of air (mg/m^3) with a mean of 3.4 mg/m^3 (Table II). Six personal breathing-zone samples for respirable particulates ranged from 0.17 to 0.88 mg/m^3, with a mean of 0.44 mg/m^3.

Four sets of side-by-side total/respirable dust samples indicated that the respirable fraction ranged from 3% to 32% with a mean of 15%. However, the detailed pattern of air-flow through cyclones depends greatly on the particular design that was developed for specific applications. For instance, the commonly used 10 mm nylon cyclone was developed to provide size selection characteristics for testing compliance with exposure limits to free crystalline silica as follows:

Aerodynamic diameter (um)	Percent passing selector
2.0	90
2.5	75
3.5	50
5.0	25
10	0

Although the 10 mm cyclone has since been found useful in separating other types of "respirable dusts", its application for sampling petroleum coke dust has not yet been evaluated.

No crystalline silica, sulfates, or sulfites were detected.

Analysis of bulk coke samples indicated that benzene extracted about 30% more of the PNA's than cyclohexane. (Table I)

The analytical results of quality control samples submitted to the laboratory showed variable recovery of some of the PNA compounds. The problem appeared to be associated with the extraction and concentration procedures.

The samples were extracted with 5-10 ml of benzene and a labeled recovery standard of 200 ng of d_{12}-crysene was spiked into each sample before extraction. The extract volume was reduced to 200 ul by blowdown with nitrogen and an internal quantitation standard of 200 ng of d_{10}-anthracene was added to each sample before HRGC/SIM/MS analysis. A one ul aliquat of the final 200 ul volume was used for injection. The mean recovery for d_{12}-chrysene was 85% + 15%. Although the method produced a good minimum quantitation level of 2 ng/sample, the recovery of d_{12}-chrysene was not found satisfactory for all samples. Moreover, some of the audit samples showed low recovery for some of PNA's. This was believed to be the result of the nitrogen blowdown procedure. Consequently, the following PNA sampling results may be low and should be considered as approximations.

Cumulative concentrations of the fourteen PNA compounds in breathing zone samples ranged from 0.10 to 36 micrograms per cubic meter (ug/m^3) with a mean of 3.8 ug/m^3 (Table 4). The coal tar pitch volatile (CTPV) benzene-soluble fraction of the personal breathing-zone samples ranged from <70 ug/m^3 to 5100 ug/m^3 with a mean of approximately 600 ug/m^3. The evaluation criterion for CTPVs is 100 ug/m^3.

Exposure to phenanthrene vapor ranged from non-detectable to 0.23 ug/m^3 with a mean of 0.07 ug/m^3.

The use of Norton Dust Respirators, Model No. 7170, is required in a few posted areas of the plant, such as conveyor transfer points, where dust levels are known to be higher. In most areas of the plant the use of respiratory protection is optional.

B. Medical

Ninety current GLC employees (55%) participated in the medical evaluation. Fifty-seven (63%) of these were hourly production workers, and the remainder were salaried personnel. Fourteen percent of the participants (all salaried) were female. Forty-one percent were white, 50% were black, and 9% hispanic.

The mean age of the participants was 40 years (range: 20-78 years). The mean length of employment was 11.6 years (range: <1 year to 36 years). Thirty-six percent of the respondents currently smoke cigarettes, 19% were ex-smokers, and 42% reported never to have smoked. Of the 61 employees who reported that they currently do not smoke, 3 workers did not provide a past smoking history.

All participants took part in the medical interview and pulmonary function testing, although three workers were unable to perform a breathing test of sufficient quality for evaluation. Seventy-one current employees had chest x-rays.

1. Questionnaire Responses

Five of the questionnaire respondents met the BMRC's case definition of chronic bronchitis (cough and phlegm production on most days for at least three months a year for two or more consecutive years). These respondents did not differ significantly from those without this set of symptoms in age, length of employment at GLC, smoking history, current department of work, history of work in high dust area, or past medical history (see Table V). Only one of these workers had abnormal pulmonary function tests.

Table VI contains information on other questionnaire responses. Reports of cough, phlegm production and shortness-of-breath were not statistically associated with age, length of employment or current department of work. Report of cough and phlegm production were not statistically associated with current cigarette smoking; however, shortness of breath was associated with current cigarette smoking (see Table VII).

2. Pulmonary Function Tests

The pulmonary function test (PFT) results of 9 (10%) current employees [8 (14%) production workers] were abnormal. One showed a restrictive abnormality, three had obstructive abnomalities and five had a combination of both types. Workers with abnormal test results were compared with those with normal results and found to be significantly older (49.6 years versus 38.4 years) (Wilcoxon signed rank test p=.009). When smoking histories of these two groups were compared, there was no significant difference in current smoking between the two groups (see Table VIII). The difference between the length of employment of those workers with pulmonary function abnormalities (17.6 yrs) and those without abnormalities (11.2 years) was not statistically significant (Wilcoxon test p=0.056). Although among current production workers (salaried employee excluded), the length of employment between the two groups was statistically different (Wilcoxon test p=0.01).

To further evaluate the association between current production workers' PFT results (percent of predicted) and length of employment at GLC, a Spearman's correlation coefficent test was performed which provided the following results: $FEV_1 = -0.25$ ($p=0.047$); $FVC = -0.24$ ($p=0.068$); $FEV_1/FVC = -0.42$ ($p<0.001$). Since the FEV_1/FVC is a ratio of volumes, it does not correct for age; therefore, this value may be reflecting age in addition to length of employment.

Among all employees, PFT decrements were significantly related to current department of employment (chi-square, p=0.022). Work in the mobile equipment department appeared to be associated with pulmonary function abnormalities (4 of 12 workers had abnormal PFTs). Because the investigation was concerned with chronic respiratory problems, pulmonary function abnormalities among workers with 5 years or more in the mobile equipment department were further evaluated. The number of workers with pulmonary function abnormalities in this group was significantly different from the number among workers with less than 5 years or no experience in mobile equipment department (Fisher's exact test - 2-tailed p=0.049). This finding is not unexpected since workers in mobile equipment spend more of their time outside (e.g. front-end loaders) than workers in other departments.

In Febuary 1981, OCAW tested the pulmonary function of 29 current and former GLC employees. Reports of these tests stated that 6 had restrictive abnormalities, 6 had obstructive abnormalities, 3 had a combination of restrictive and obstructive abnormalies, and 2 were borderline abnormal. The remainder were normal.

Fourteen of these workers participated in the NIOSH study in January. Seven of them had normal results on both the union and NIOSH administered tests, two workers had restrictive or a combination of restrictive and obstructive abnormalities on both tests. Two workers had abnormal results when tested by the union and normal tests by NIOSH, the reverse was true in another worker. Three additional workers had abnormal results on both tests, but the type of abnormality differed between tests.

A large amount of variabilty in test results can occur when equipment, technicians, and method of testing are not standard from one study to another. Therefore, it is not unexpected that the union administered test results might different in some cases from NIOSH's results.

3. Chest X-rays

Sixty-three of the 71 chest x-rays were completely normal. Six films had some type of abnormality which was most likely unrelated to any contaminant in the environment (e.g. cardiac enlargement, post open heart surgery, lung bullae). Two x-rays were classified as having evidence of pneumoconiosis by one "B reader". One of these films was described as having small (1.5 mm to 3.0 mm in diameter) rounded opacities, with a profusion rate of 1/0 (opacities which are few in number) in both upper zones of the lungs. The second film had small rounded opacities in the upper right zone with a profusion rate of 0/1. A profusion of 0/1 is interpreted as essentially normal with some question of a few opacities. The second reader classified both of these films as negative for pneumoconiosis.

Pneumoconiosis (dust disease) associated with exposure to coal dust, is characterized by opacities, generally round in shape with a profusion based on the progression of the disease. One of these two cases qualifies as pneumoconiosis (profusion of 1/0) and this individual reported a history of employment in a foundry. Since silicosis among foundry workers has been well documented, it is difficult to relate these radiologic changes to his current work environment.

The results of the retirees' medical tests were not included in the above analyses. The mean age of the five retirees tested was 68.2 years, the mean length of employment was 20.9 years. Four of the five retirees had abnormal PFTs (2 - obstructive , 2 - combination of obstructive/restrictive). Three of the five met the case definition of chronic bronchitis on questionnaire evaluation. The four retirees with abnormal PFT results reported smoking histories with a mean duration of 30 years. Three of these workers were former mobile equipment operators and one was a laborer. None of their x-rays showed evidence of pneumoconiosis. Two of the films had some abnormality which was most likely unrelated to exposures at GLC (evidence of a pacemaker, pleural adhesion).

4. Death Claims

GLC death claims from 1968-1981 (the only years for which the company has collected this data) reported 40 deaths by cause and year of death. Six of these deaths were recorded as a cancer death and included the following: 1 stomach cancer, 2 cancers - site unspecified, 3 lung cancers (1 occurring in 1969 and 2 in 1981). A crude evaluation of these deaths was performed by comparing the proportion of lung cancer deaths among all recorded deaths within the GLC population with similar data from the total U.S. male population. 1974 was chosen as a reference year since it was midway through the years 1968-1981. Table IX contains a comparison of the proportions of deaths from lung cancer and all types of neoplasms for these two groups.

The proportion of reported GLC deaths from all neoplasms does not appear to be in excess of what would be expected from this cause, based on U.S. total male population figures. The proportion of lung cancer deaths among all deaths at GLC was slightly higher than that seen in the U.S. total population (7.5% versus 5.8%) for a proportional mortality ratio (PMR) of 1.29. However, this difference was not statistically significant. This is a crude method of evaluating this data and neither confirms nor refutes the possibility that an actual excess of lung cancer deaths have occurred at GLC. It is difficult to come to any conclusion about an excess in cancer deaths considering the overall small number of deaths recorded to date and the fact that this is probably only a partial list of the deaths that have occurred.

Various PNAs have been found to be carcinogenic in animal and human studies. At this time, however, it is not possible to relate cancer deaths among GLC employees to PNA exposure. A long-term mortality study would be needed to investigate this relationship. Recommendation for collecting mortality data are included in Section VIII of this report.

VII. CONCLUSIONS AND DISCUSSION

The environmental data indicate that workers located outdoors and working with or near mobile equipment (e.g. front-end loaders) and conveying machinery (e.g. silo operators) are overexposed to petroleum coke dust containing PNAs.

Nine of the 14 PNA's that were identified are listed as having some cancer-causing potential in the 1980 NIOSH Registry of Toxic Effects of Chemical Substances. Since no safe levels of exposure to carcinogens have been demonstrated, it would be prudent to reduce these exposures to the lowest possible levels. More effective methods of dust suppression, process enclosure, and worker isolation are needed at Great Lakes Carbon.

The environmental criterion currently used by Great Lakes Carbon is not appropriate for assessing worker exposure to petroleum coke dust. "Nuisance dust" standards should not be applied to materials that contain carcinogens. Also, the carbon black standard that has been referenced by previous investigators may be inadequate for evaluating petroleum coke exposure. The 3.5 mg/m^3 standard was intended to prevent excessive exposure to CTPV's. However, at the time of the NIOSH investigation, the average dust exposure among workers at GLC was only 3.4 mg/m^3, whereas the average exposure to CTPV's was six times the NIOSH recommended standard. Furthermore, the actual PNA constituent of the petroleum coke used during the NIOSH study was higher than that found in some carbon blacks. Moreover, exposure to the volatile form of one of the PNA's, phenanthrene, was found. This finding indicates that petroleum coke may have weaker PNA adsorptive properties than carbon black.

Chronic bronchitis was reported among 5 current employees. These symptoms were not associated with exposure to coke dust as measured by length of employment at GLC, current department of work, or a history of work outdoors. Workers reporting this group of symptoms did not significatly differ in current cigarette smoking from those without symptoms (40% vs 36%) nor did they have a past medical history (i.e. bronchitis, tuberculosis) which would have contributed to these complaints. Thus, the etiology of their bronchitis is uncertain.

Pulmonary function abnormalities were recorded among 9 workers. These abnormalities were significantly related to the workers' current department of work. Workers who had spent 5 years or more in the mobile equipment department at any time during their employment at GLC had a significantly higher rate of PFT abnormalities than those with less than five years or no exposure in this department. PFT abnormalities among production workers were correlated with length of employment at GLC and did not appear to be totally explained by cigarette smoking. Fifty-six percent of those with abnormal pulmonary function tests were cigarette smokers compared to 35% of those with normal pulmonary function tests ($p > .10$).

Most historical reports of chronic lung disease among carbon workers are based on radiological findings. None of the x-rays performed during this evaluation showed pneumoconiosis which could be associated with coke dust exposure at GLC. The one worker with radiologic evidence of pneumoconiosis reported a history of employment in a foundry, an industry with known silica exposure. Based on these findings, pneumoconiosis does not appear to be present among employees tested during the NIOSH evaluation.

Although only 66% of the production workforce participated in the study, notification of medical testing was posted and made available to all employees. Therefore, it appeared that this group was representative of the current workforce.

A crude method of evaluating excess cancer deaths was employed. The proportion of cancer deaths among total reported deaths at GLC was compared with this proportion for the total U.S. male population (1974). The proportion of lung cancer deaths among all deaths at GLC was in excess, although not statistically significant, of what would be expected based on national figures. The total number of recorded deaths was very small, making it nearly impossible to detect an excess in cause-specific deaths except for instance in the case of a very rare type of cancer not seen from other causes. Since the recorded deaths were based on death claims, the list probably does not include all deaths occurring during the years 1968-1981. Continuous mortality surveillance is recommended, especially since two of the deaths in question (lung cancer deaths) occurred as recently as 1981. NIOSH did not collect any further information regarding deceased employees, and therefore cannot evaluate other lung cancer-related factors such as smoking, work, or family history.

The medical data collected during the NIOSH investigation suggest that pneumoconiosis does not exist among the current workforce tested during the evaluation, but pulmonary function abnormalities were recorded and appear to be associated with workplace exposures as measured by length of employment and department of employment.

VIII. RECOMMENDATIONS

1. More effective methods of airborne dust suppression should be used when storing and handling petroleum coke. The water spraying techniques that are presently being attempted for this purpose do not appear to be very efficient, primarily because water does not readily mix with coke. If large quantities of coke must be stored outdoors, the application of various oils or lacquers could be more effective in reducing airborne dust exposures.

2. The conveyor systems that transport coke to the kilns should be enclosed to help reduce dust emissions.

3. Mobile equiment operators should be better isolated from excessive outdoor dust levels by enclosing the cabs more tightly.

4. Pre-employment pulmonary function tests (including FEV_1 and FVC) and chest x-rays (posterior-anterior and lateral) which the company instituted in 1980 should be continued and should include a physical examination with special emphasis directed toward the respiratory system and skin.

5. Medical surveillance consisting of the above mentioned PFTs, chest x-rays and physical exam should be made available to all production workers on a periodic basis.

6. Death claim reporting, as was done for the period 1968-1981 should be continued by GLC.

7. The union and/or company should maintain a record of deaths of all workers/union members with long-term employment at GLC (perhaps greater than five years). Minimal information collected should include full names, date of death and social security number.

8. Death certificates should be obtained on all deaths. Workers' families should be encouraged to have autopsies performed on deceased workers in the case of a cancer death for which no biopsy had been performed, or if the cause of death is in question.

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, 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. Great Lakes Carbon Corp., Port Arthur, Texas
2. Great Lakes Carbon Corp., Niagara Falls, N.Y.
3. Authorized Representative of Employees, Local 201, Oil, Chemical, and Atomic Workers Union
4. Oil Chemical & Atomic Workers International Union
5. NIOSH, Region VI
6. OSHA, Region VI

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

PNA Content of Petroleum Coke, Calcine, and Various Carbon Blacks* (ppm)

Substance	Extraction (solvent/hours)	Anthracene	Fluoranthene	Pyrene	Pyrene: Benzo (a)	Pyrene: Benzo (e)	Indeno (123CD)	Benzo (GHI) Perylene
Petroleum Coke	Benzene/24	2.9	2.9	19	12	23	1.9	11
Petroleum Coke	Cyclohexane/24	1.7	3.9	18	6.7	13	0.7	3.8
Calcine	Benzene/24	0.9	1.6	2.5	0.7	0.7	N.D.**	0.6
Calcine	Cyclohexane/24	0.3	0.2	1.6	0.3	0.3	N.D.	N.D.
Channel Black ASTM RCC	Toluene/48	N.D.	0.2	0.3	0.1	0.1	N.D.	0.7
Channel Black ASTM S301	Toluene/48	N.D.	0.5	0.3	0.11	0.2	0.1	0.5
Furnace Black ASTM N472	Toluene/48	N.D.	1.0	0.5	N.D.	-†	N.D.	N.D.
Furnace Black ASTM N375	Benzene/250	45	58	315	20††		24	166
Furnace Black ASTM N326	Benzene/250	-	9	58	1.0††		1.0	16
Furnace Black ASTM 330	Benzene/250	2.0	10	48	3.0††		0.3	25
Thermal Black ASTM N990	Benzene/24	300	200	600	190	145	-	220

*Rivin, D. et al. "Environmental Health Aspects of Carbon Black", Rubber Chemistry and Technology, Vol. 55, No. 3, 1982

**N.D. = none detected

†- = not analyzed

†† = a and e isomers were not separated

TABLE II

Personal Breathing-Zone Samples for Total and Respirable Particulates, Respirable Crystalline Silica, Sulfates, and Sulfites

Great Lakes Carbon Corporation
Port Arthur, Texas
HETA 81-421

January 26 & 27, 1982

Job/Location	Sampling Period	Total Particulate Concentration (mg/m^3)	Respirable Particulate Concentration (mg/m^3)	% Respirable Particulates	Respirable Crystalline Silica	Sulfates and Sulfites
Unloading Operator	8:15-14:45	2.2	0.26	12	N.D.*	N.D.
Silo Operator	8:18-14:45	6.1	0.88	14	N.D.	N.D.
Ship Loading Operator	8:25-15:10	5.9	0.17	3	N.D.	N.D.
Front End Loader	15:00-21:30	1.2	0.38	32	N.D.	N.D.
B Operator	7:41-14:45	-**	0.64	-	N.D.	-
6 Operator	8:00-15:16	-	0.25	-	N.D.	-
Operator Helper	7:40-15:16	2.9	-	-	-	N.D.
Operator Helper	8:00-15:16	4.2	-	-	-	N.D.
Car Unloader	14:50-21:35	1.5	-	-	-	N.D.

* N.D. = none detected
** - = not analyzed

TABLE III

Airborne Particulate PNA Sampling Results in ug/m3

Great Lakes Carbon Corporation
Port Arthur, Texas
HETA 81-421

January 26-27, 1982

Job/Location	Sampling Period	Benzene Soluble Fraction Concentration	Cumulative PNA Concentration	Phenanthrene*	Anthracene*	Fluoranthene	Pyrene*	Benz (A) Anthracene*	Chrysene*	Fluoranthene Benzo (B)	Fluoranthene Benzo (K)	Pyrene* Benzo (E)	Pyrene* Benzo (A)	Perylene	Indeno* (123CD) Pyrene	Benzo* (GHI) Perylene	Dibenz* (AH) Anthracene
Front End Loader	8:06-14:45	1600	1.1	0.07	0.02	0.02	0.07	0.09	0.16	0.09	N.D.*	0.13	0.09	0.01	0.04	0.09	0.05
Front End Loader	8:10-14:45	280	3.5	0.20	0.01	0.13	0.18	0.34	0.52	0.27	N.D.	0.46	0.38	0.02	0.09	0.26	0.45
Front End Loader	15:00-21:32	<70	0.76	0.03	0.02	0.02	0.07	0.08	0.12	0.07	N.D.	0.10	0.08	0.01	0.03	0.05	0.08
Front End Loader	7:41-14:38	<70	0.56	0.04	0.02	0.02	0.07	0.03	0.04	0.06	N.D.	0.10	0.09	0.10	0.01	0.05	0.05
B Operator	7:23-14:50	170	0.44	0.03	0.01	0.01	0.02	0.04	0.06	0.04	N.D.	0.05	0.04	0.01	0.01	0.05	0.02
B Operator	7:31-14:50	80	0.65	0.04	0.01	0.01	0.05	0.06	0.09	0.05	N.D.	0.08	0.07	0.01	0.03	0.06	0.03
Operator Helper	7:35-14:51	1100	6.9	0.31	0.15	0.12	0.54	0.57	1.2	0.66	N.D	0.95	0.80	0.11	0.28	0.80	0.36
Operator Helper	7:55-14:54	<70	0.37	0.02	0.01	0.01	0.03	0.03	0.05	0.03	N.D.	0.04	0.03	0.01	0.01	0.03	0.02
Car Unloader	14:50-21:35	<70	0.74	0.06	0.01	0.02	0.07	0.07	0.12	0.06	N.D.	0.01	0.08	0.01	0.02	0.05	0.07
Car Unloader	15:05-21:35	70	1.2	0.07	0.02	0.05	0.10	0.10	0.19	0.09	N.D.	0.13	0.10	0.02	0.05	0.10	0.06
Unloading Opr.	7:38-14:37	<70	0.29	N.D.	0.01	0.01	0.02	0.02	0.04	0.02	N.D.	0.03	0.02	0.01	0.01	0.02	0.01
Unloading Opr.	14:57-21:30	<70	0.10	0.02	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Silo Operator	15:10-21:50	320	2.9	0.14	0.10	0.05	0.24	0.22	0.47	0.22	N.D.	0.37	0.35	0.05	0.11	0.34	0.18
Sample Operator	8:22-14:45	<70	1.4	0.17	0.03	0.40	0.12	0.09	0.19	0.19	N.D.	0.15	0.12	0.01	0.04	0.11	0.06
Maintenance Helper	7:26-14:59	5100	36	2.4	0.90	0.70	3.3	3.6	6.2	3.0	N.D.	4.7	3.9	0.42	1.6	3.3	2.1
Area Sample Calcine Transfer House	8:10-13:18	1600	0.20	0.06	0.03	N.D.	N.D.	N.D.	0.02	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.01
Area Sample Dedusting Oil Station	8:15-13:15	3300	1.1	0.09	0.20	0.14	0.14	0.16	0.16	0.03	N.D.	0.07	0.06	N.D.	0.01	N.D.	N.D.
Area Sample Lunchroom	8:10-15:00	230	0.43	0.02	0.01	0.01	0.02	0.02	0.04	0.02	N.D.	0.03	0.02	0.01	0.01	0.02	0.01

* These compounds are listed as having some cancer-causing potential in the 1980 NIOSH Registry of Toxic Effects of Chemical Substances.
** N.D. = none detected

TABLE IV

Volatile Phenanthrene Sampling Results in ug/m^3

Great Lakes Carbon Corporation
Port Arthur, Texas
HETA 81-421

January 26-27, 1982

Job/Location	Sampling Period	Phenanthrene
Front End Loader	8:06-14:45	0.23
Front End Loader	8:10-14:45	0.10
Front End Loader	15:00-21:32	N.D.
Front End Loader	7:41-14:38	N.D.
B Operator	7:23-14:50	0.06
B Operator	7:31-14;50	0.06
Operator Helper	7:35-14:51	0.05
Operator Helper	7:55-14:54	0.05
Car Unloader	14:50-21:35	N.D.
Car Unloader	15:05-21:35	0.08
Unloading Operator	7:38-14:37	0.08
Unloading Operator	15:10-21:50	0.08
Silo Operator	15:10-21:50	0.03
Sample Operator	8:22-14:45	0.03
Maintenance Helper	7:26-14:59	0.09
Area Sample - Calcine Transfer House	8:10-13:18	0.08
Area Sample - Dedusting Oil Station	8:15-13:15	0.07
Area Sample - Lunchroom	8:10-15:00	0.19

N.D. - non detectable

TABLE V

Current Smoking Status Reported by Workers and
Questionnaire Diagnosis of Chronic Bronchitis

Great Lakes Carbon Corporation
Port Arthur, Texas
HETA 81-421

		Questionnaire Diagnosis Yes	No	
Current Smoker	yes	2	31	33
	no	3	54	57
		5	85	90

Chi-square .025 p=0.87

TABLE VI

Great Lakes Carbon Corporation
Port Arthur, Texas
HETA 81-421

Symptom	No. of Respondents Reporting Symptom
"cough first thing in the morning for at least 3 mo./yr"	20 (22%)
"phlegm production first thing in the morning for at least 3 mo./yr."	21 (24%)
"shortness-of-breath when hurrying on level ground or up a slight hill"	32 (36%)
"shortness-of-breath when walking on level ground with people your own age"	9 (8%)
"shortness-of-breath requiring you to stop and catch your breath"	5 (5%)
wheezing	32 (35%)
eye problems	3 (3%)
skin problems	4 (4%)
others (variable responses)	(16%)

TABLE VII

Current Smoking Status Reported by Workers and Questionnaire Responses

Great Lakes Carbon Corporation
Port Arthur, Texas
HETA 81-421

Cough*

		Yes	No	
Current Smoker	yes	10	23	33
	no	10	47	57
		20	70	90

Chi-square 2.425, p >.10

Phlegm*

		Yes	No	
Current Smoker	yes	11	22	33
	no	10	47	57
		21	69	90

Chi-square 2.91, p >.05

Shortness-of-Breath

		Yes	No	
Current Smoker	yes	18	15	33
	no	14	43	57
		20	70	90

Chi-square 8.29, p <.01

* "First thing in the morning for a least 3 mo./yr."

TABLE VIII

Current Smoking Status Reported by Workers and PFT Results

Great Lakes Carbon Corporation
Port Arthur, Texas
HETA 81-421

		PFT		
		Abnormal	Normal	
Current Smoker	yes	5	28	33
	no	4	51	55
		9	79	88*

Chi-square 1.39 $p > 0.10$

* Two participants were unable to perform PFT of sufficient quality for evaluation.

TABLE IX

GLC Death Claims (1968-1981)

Great Lakes Carbon Corporation
Port Arthur, Texas
HETA 81-421

	Total deaths all causes	All neoplasms	Neoplasms of lung
GLC (1968-1981)	40	6 (15%)	3 (7.5%)
U.S. males (1974)	1,071,627	199,194 (18.6%)	61,611 (5.8%)

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