U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
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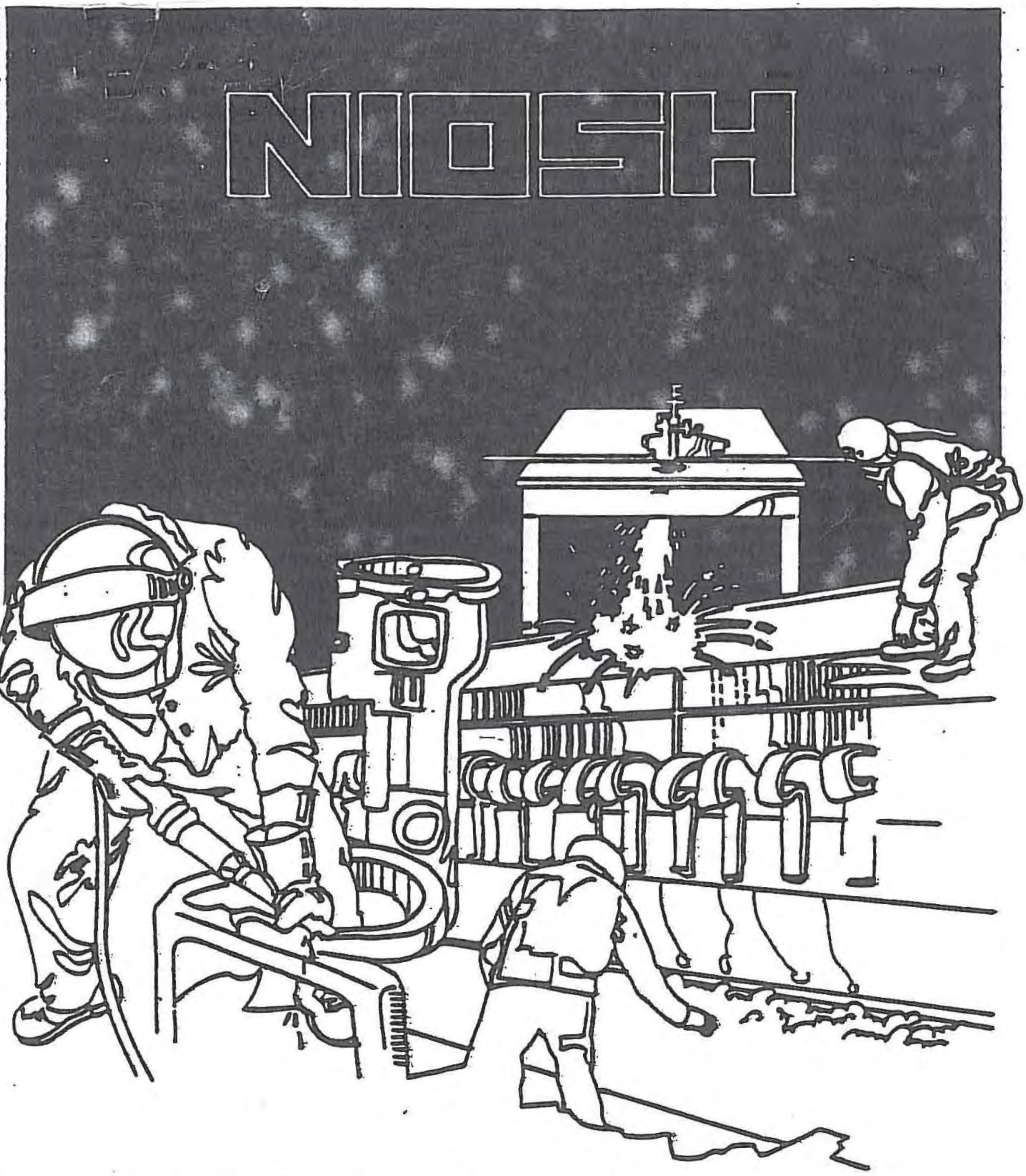

Health Hazard Evaluation Report

HETA 81-372-1727
EXXON CORPORATION, BAYWAY
REFINERY AND CHEMICAL PLANT
LINDEN, NEW JERSEY

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.

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

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EXXON CORPORATION, BAYWAY
REFINERY AND CHEMICAL PLANT
LINDEN, NEW JERSEY

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I. SUMMARY

In June, 1981, the National Institute for Occupational Safety and Health (NIOSH) received a request to evaluate the potential hazards of asbestos exposure at the Exxon Bayway Refinery and Chemical Plant in Bayway, New Jersey. The request was prompted by the report of five cases of asbestos related disease.

In order to evaluate the potential asbestos hazards in workers involved in oil refining, a radiographic survey was conducted. Five hundred and fifty (550) workers in a large oil refinery and petrochemical plant were studied. All workers in the study had a minimum of 20 years of employment at the refinery.

The reading of chest X-rays was done by two certified "B" readers using the ILO/UC Classification System for Pneumoconioses. The results were compared to the results from the Exxon asbestos medical surveillance program as well as previous studies of comparable work forces.

Radiological evidence of parenchymal interstitial fibrosis was found in 55 (11%) of the group studied. Pleural fibrosis and/or calcification was found in 126 (25%) of the subjects. The prevalence of any asbestos-related abnormality was 156 (31%) of subjects. The prevalence of pleural disease was significantly higher among those employed in higher asbestos-exposure catagories and among those with greater weighted average exposure.

Pleural abnormalities were more prevalent than parenchymal abnormalities. The risk of developing severe disabling pulmonary fibrosis seems to be minimal since few of the cases had small irregular opacities graded 2/1 or higher. Based on the positive X-ray findings for asbestos-related abnormalities, this population has had sufficient exposure to asbestos to have an increased risk of excess lung cancer and/or mesothelioma.

In this group of oil refinery and petrochemical workers chest X-ray abnormalities were present in moderate numbers, pleural abnormalities being more prevalent than parenchymal. Relationships were found both between pleural X-ray abnormalities and estimates of exposure and parenchymal abnormalities and estimates of exposure. The analyses showed that chest X-ray abnormalities could be found across all work categories and that, with some exceptions, there was a positive association between the length of time worked in different categories and X-ray abnormalities This supports the assertion that exposure at the refinery was dispersed and widespread. Recommendations (presented in the final section of this report) include enclosing operations and/or providing local exhaust ventilation at the site of asbestos release. Isolating operations was suggested for reducing exposure. In addition, recommendations for baseline and periodic medical examinations are made .

KEYWORDS: SIC 2011, asbestos, pleural disease, parenchymal disease, chest radiography, occupational lung disease, screening

II. INTRODUCTION

On June 29, 1981 the National Institute for Occupational Safety and Health received a request from the President of Teamsters Local 877 to evaluate the hazards of asbestos exposure at the Exxon Bayway Refinery and Chemical Plant (SIC #2911) Linden, New Jersey. The request was prompted by the report of five cases of asbestos-related disease on the OSHA Log 200 in February, 1981 plus the existence of twenty possible additional cases under review. The hazard evaluation was assigned to the New Jersey State Department of Health (NJDOH) under a Cooperative Agreement. Shortly after receiving the request, the NJDOH initiated an investigation followed by an interim report outlining the steps described in this report.

III. BACKGROUND

Exxon Bayway is an oil refinery and petrochemical plant which has been located in Linden, New Jersey since the early 1900's. It currently employs a work force of about 2,100 and encompasses an area of 1700 acres. The refinery has the capacity to handle 330 thousand barrels of crude oil a day, though it presently is operating at less than capacity. The petrochemical plant is concentrated in two areas of the Bayway site which are each about 100 acres. The Paraffins and Specialties Division produces a variety of fuel additives and polymerized hydrocarbons in batch operations. The Chemical and Manufacturing Division produces solvents in an essentially continuous process.

Asbestos has been used extensively as an insulation material throughout the work place. The substitution of non-asbestos insulation and the establishment of procedures to reduce asbestos exposure dates from 1972 with passage of the OSHA standards.

On September 8, 1981, an initial site visit to the refinery and petrochemical plant was conducted by two physicians and an industrial hygienist. The NJDOH met jointly with management and union representatives. A brief tour through the work site took place to provide an overview of the work site as well as an opportunity to inspect areas where asbestos insulation was poorly maintained. The NJDOH industrial hygienist met with the refinery and petrochemical plant hygienists to review monitoring records and personal protection practices. The company's medical director met with the physicians to review the quality and availability of medical records as well as the details of the asbestos surveillance program.

Exxon presently has about 2100 employees at the Bayway site: two-thirds (1400) work at the plant and the remaining 700 work at the petrochemical plant. Given a highly stable work force whose major hiring periods occurred before 1950 and after 1965, the men are divided by age into two groups. The older workers, mostly hired before 1950, have worked for twenty or more years and within the time period where the risk of showing abnormal chest X-rays or developing cancer is more likely. By 1981 many of these older workers had retired so only 25% of the current work force is over 40 years of age. There are 698 annuitants who have retired since 1965 (alive and deceased).

Most of the current workers are younger men hired since 1965. They have many fewer years of potential asbestos exposure than the older workers. Also, they have been presumably exposed to progressively lower levels than the exposures of earlier years. At this point any risk assessment for these younger workers would be an underestimation since we know that it may take up to twenty years of exposure to manifest disease. Estimating risk among the younger work force by generalizing from the experience of the older and retired workers is also not likely to be valid.

Within the refinery and petrochemical plant, certain jobs have always had increased exposure to asbestos. Over the years, the union has "consolidated" its job categories so that workers may perform a greater range of activities than under the previous emphasis on a particular craft.

The insulators have been consolidated with the carpenters and masons into the Building Section Craft. Since a 1969 strike most of the construction has been subcontracted to outside workers and much of the activity of the Building Craft consists of repairs, errecting scaffold and partitions. The Metal Craft Section includes pipe fitters and welders who presumably also have significant asbestos exposure. As estimated by both union and management, intermediate exposure is experienced by the machinists in the Equipment Section Craft when repairs are needed in the field or the central plant. Electricians, instrument workers, transportation operators, process operators, and supervisors all experience low level exposures. The process operators have a limited bystander exposure to asbestos. They work on rotating shifts while much of the mechanical work takes place on the daytime shift.

Exxon Bayway has performed routine physical exams since 1925. On-site chest X-rays date from 1944-45. Initially, only workers exposed to asbestos and dust received chest X-rays on a regular schedule. By 1949 all workers were having chest X-rays and physical exams at intervals of 1 to 3 years. Pulmonary function tests have been done since 1977. The medical department has kept all records and radiographs. Some records suffered flood damage (1968) and some X-rays have gone to the employee's personal physician.

In 1980-1981 the corporation medical director instituted a more comprehensive medical asbestos surveillance program. He had a "B"-reader review the chest X-rays of the 450 men over age 40. The radiologist identified 5 cases of "asbestosis" (pleural plaques primarily) which were reported to the particular individuals and listed on the OSHA 200 form. There were another 8 to 9 cases of pleural abnormalities in this group, which are probably asbestos-related but have not yet been reported. Finally, there are from 15 to 20 cases who have pleural abnormalities on chest X-ray that the radiologist felt could not be characterized as asbestos-related. Therefore, depending on how many of these chest X-ray are considered positive the prevalence of asbestos-associated pleural abnormalities ranges from 1% to 7%. These figures are much lower than rates reported for a comparable population (2).

Exxon Research Division has completed a mortality study for Bayway in addition to two other Exxon refineries(11). They examined the mortality experience for 5,780 employees and retirees between 1970 and 1977. The authors concluded the slightly elevated disease specific mortality ratios merited further review. It should be pointed out that their conclusions were based on data which did not specifically categorize the work force by asbestos-related responsibility.

Since 1972, only non-asbestos insulation materials have been installed in the refinery and chemical plant. Of the current insulation, 80-90% is estimated to date before 1972 and probably consists of asbestos materials. None of the insulation seen on the site visit was identified as to whether or not it contained asbestos. The older insulation seen was in poorer, friable condition, frequently not completely maintained around joints and control points. No active insulation removal was taking place during the 1981 visit.

The company has guidelines for asbestos handling which date back to 1978. The regional EPA Office in New York City is notified for asbestos removal of more than 260 square feet or 150 linear feet, to ensure proper handling and disposal of asbestos. In the first 10 months of 1981, EPA was notified six times. These major asbestos removal projects are performed by several subcontractors. At the time of the site visit, there did not appear to be precise criteria for determining whether a job requiring disruption of the insulation will be done by Exxon employees or these outside contractors.

When contractors are used for an asbestos removal job, air monitoring for asbestos is performed at the perimeter of the job site. The purpose is to evaluate the exposure to Exxon employees from air-borne asbestos being generated. Personal air samples were also taken on Exxon employees during 1978-1980 while they performed small jobs requiring asbestos handling. Results for time-weighted exposures were all reportedly below the two fiber/cc OSHA standard.

Most of the asbestos insulation on this work site is located outdoors, a fact which tends to lower air concentrations but increase dispersal. The net effect on the risk due to exposure is unknown. Some of the insulation is located indoors where higher air concentrations of asbestos could conceivably be generated. Bulk samples have been taken in 81 such indoor locations, and 9 areas with asbestos have been identified.

Workers expressed concern that recommended work practices are not always followed on small repair jobs. The effectiveness of the training in asbestos handling at the time of original site visit was questionable. An equally serious question was raised amongst workers as to whether outside contractors used work practices which would eliminate bystander exposure.

The union request was directed at the results and content of the current medical and hygiene surveillance program. The requestors did not know the prevalence of asbestos-associated parenchymal and pleural abnormalities among their active and retired union members. Finally, there was concern about the long-term health effects of low level asbestos exposure.

In essence, from the requester's perspective the primary objective of the evaluation was to determine more precisely the prevalence of asbestos-associated parenchymal and pleural abnormalities among their active and retired union members and based on this determination provide recommendations for improving medical surveillance and prevention of asbestos-related disease.

IV. METHODS

A. Environmental

Exact measurements of asbestos dust in the various past and current work environments at Exxon did not exist. In order to derive an estimate of historical exposure, a six person panel made up of Exxon management and labor as well as representatives from NJDOH was constructed. The panel devised an exposure scheme which corresponded to the work categorization seen in Table 1. Category A1 was estimated to include the jobs with the highest exposure to asbestos, D1, the category where the least exposure would likely occur. We obtained the personnel records on each worker and, using this categorization scheme, coded all jobs held by a given worker at the refinery for at least one month. The duration of each job in months was also recorded.

B. Medical

The main focus of the HHE was to assess the prevalence of chest X-ray abnormalities consistent with asbestos-related disease within the active and retired work force. We reviewed chest X-rays of men with at least twenty years duration at Exxon. Chest X-ray reading was performed by two certified "B" readers using the ILO/UC Classification System for Pneumoconioses. Ten percent of all X-rays read were co-read blindly by the "B" readers. This was done to provide a means of "calibrating" the interpretation of the primary "B" reading. Questionable cases among the 10% sample were resolved by consensus. The two "B" readers are members ofthe same Radiology Department and have collaborated on numerous standardized X-ray surveys in the past. The results were compared to the results from the Exxon asbestos medical surveillance program as well as previous studies of comparable work forces.

1. Cohort description

a. Derivation of working group

All refinery workers who had retired since 1968 or who were current workers as of 1982 with at least 20 years of employment were eligible for the study. We obtained the most recent chest X-ray (postero-anterior view only) available for each worker.

Five hundred and fifty (550) total Exxon workers, both current and retired, comprised the population for which either chest X-rays or work histories were available. Twenty (20) workers did not meet the study eligibility requirement of at least 20 years of Exxon service. Of the remaining 530, 17 workers had X-rays of technical quality '4' (unreadable) based on the International Labor Office X-ray film quality scale. Twelve (12) workers had no available X-rays. Thus 501 workers had readable X-rays. Twenty-four (24) of the remaining workers had no available work histories. There were thus 477 workers with both readable chest X-rays and available work histories (Table 2). Among those with both readable chest X-rays and available work histories were 105 current workers and 372 retired workers.

b. Work/exposure history characteristics of the cohort

Focusing on categories 'A' and 'B' (the presumed higher asbestos exposure categories), the average durations were quite similar, although current workers averaged slighty more years in Category A (6.8 versus 5.7) and retired workers slightly more in Category B (21.7 versus 19.7).

Exposure to asbestos was also assessed using two derived measures or indexes: total exposure months (EM) and weighted average exposure (WAE). These indexes were developed in order to deal with the great mixture of jobs most individuals in the evaluation had.

In order to derive exposure months, the number of months was calculated for each worker by first assigning a numerical weight to each of the four major work categories: (A=4, B=3, C=2, and D=1). Next, this numerical weight was multiplied for each of the jobs he worked during his career the refinery by the number of months that the individual worked in that job category. Finally, the results of the multiplication for each were added to give the total exposure months for an individual. For example, if a worker had worked thirty months in a 'B' category job and twenty-four months in a 'C' category job, his total exposure months would equal ((3 X 30) + (2 X 24)) or 138 exposure months.

The weighted average exposure for each individual was calculated by dividing the total number of exposure months as calculated above by the absolute total number of months worked at Exxon regardless of job category. The weighted average exposure for the above individual would be (138/(30 + 24)) or 2.56.

EM averaged 1208.7 for the entire group (N=477). The retired workers averaged 1213.9 EM, current workers 1190.4: not statistically different (p = 0.456).

The entire group had an average WAE of 2.90. The retired workers had an average WAE of 2.92, current workers 2.86: again, not statistically different (p = 0.33).

Finally, latency (the elapsed time from original exposure in each work category to time of X-ray) was assessed for the entire group having both readable X-rays and available work histories. Latency was virtually equal in the current and retired workers. Mean latency was 34.4 years.

2. ILO categorization scheme

Chest X-rays were read by physicians ("B" readers) trained and certified to read chest X-rays of people with work-related diseases (pneumoconioses). X-rays were read and classified according to the guidelines of the International Labor Office (ILO). This classification process permits semiquantitative interpretation of X-rays to identify early evidence and progression of parenchymal and pleural disease; it focuses on size, shape, concentration, and distribution of small parenchymal opacities as well as distribution and extent of pleural thickening or calcification (Appendix A).

3. Parenchymal disease definition (S,T, or U and profusion >= 1/0)

In the analyses of the prevalence of asbestos-associated parenchymal disease (including that disease related to job (asbestos) exposure) two criteria or definitions had to be met:

a. Parenchymal disease profusion type had to be s, t, or u; i.e. irregular opacities which are indicative of the interstitial fibrotic process seen in asbestosis. All those with X-rays having p's, q's, or r's (denoting rounded opacities) in both primary and secondary categories were excluded from analysis.

b. X-rays were tallied as positive for parenchymal disease only if the "B" reader ruled that there were parenchymal findings consistent with pneumoconiosis and if the degree of profusion was read as '1/0' or greater.

4. Pleural disease definition

X-rays were tallied as positive for pleural disease if the "B" reader ruled that the X-ray had pleural findings consistent with asbestos-related disease and pleural findings other than just unilateral (one-sided) costophrenic angle blunting were present.

5. Only workers with at least 20 years of work experience at Exxon were included in the analysis of the relationship of work history to asbestos-related X-ray abnormalities.

V. EVALUATION CRITERIA

A. General

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.

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 US 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 evaluation 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 the 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 exposure.

B. Asbestos

Asbestos exposure can produce two major types of abnormalities that can be viewed on chest X-rays: pleural abnormalities, which are thickening, plaques or calcification in the pleural membranes surrounding the lung; and parenchymal abnormalities, which are due to thickening of the walls of the tiny air sacs in the lungs themselves. The International Labor Organization/University of Cincinnati (ILO/UC) System is a standardized system for grading the degree of these abnormalities seen on X-rays by physicians(1).

Parenchymal fibrosis is generally seen in workers with extensive asbestos exposure and can be accompanied by impairment of pulmonary function. Pleural thickening and plaques can be seen on radiographs of workers with extensive asbestos exposure as well as low level exposure, including bystanders without direct asbestos exposure. These pleural X-ray abnormalities are not usually associated with impairment of pulmonary function.

Oil refinery and petrochemical plant workers have been shown to be at risk for asbestos-related pleural disease and interstitial pulmonary fibrosis (2). In addition, mortality studies have indicated an unexplained elevated risk for lung cancer (3) and mesothelioma (3) among long-term refinery workers. Asbestos exposure in refineries is generally thought to be lower than that experienced by insulators, asbestos miners or asbestos product workers. Therefore, the spectrum of health effects is expected to shift so that pleural abnormalities predominate. The union was concerned about the prevalence and consequence of these pleural abnormalities among members of the work force who had little direct or extensive exposure to asbestos. The prognostic significance of these pleural abnormalities is presently unclear. However, one study of British shipyard workers indicated a greater than two-fold increase in risk for lung cancer among workers with plaques as compared to age-matched workers who were free of plaques(10). Other studies have found that plaques are associated with subtle pulmonary function abnormalities.

Available studies provide conclusive evidence that exposure to asbestos fibers causes cancer and asbestosis in human beings. Mesotheliomas, lung and gastrointestinal cancers have been shown to be excessive in occupationally exposed persons, while mesotheliomas have developed also in individuals living in the neighborhood of asbestos factories and near crocidolite deposits, and in persons living with asbestos workers. Asbestosis has been identified among persons living near anthophyllite deposits.

There are data that show that the lower the exposure, the lower the risk of developing cancer. However, evaluation of all available human data provides no evidence for a threshold or for a "safe" level of exposure to asbestos.

In view of the above, NIOSH believes the standard should be set at the lowest level detectable by available analytical techniques, an approach consistent with NIOSH's most recent recommendations for other carcinogens. Such a standard should also prevent the development of asbestosis. Since phase contrast microscopy is the only generally available and practical analytical technique at the present time, this level is defined as 100,000 fibers greater than 5 microns in length per cubic milliliter (0.1 fibers/cc), on an 8-hour-TWA basis with peak concentrations not exceeding 500,000 fibers greater than 5 microns in length per cubic milliliter (0.5 fibers/cc) based on a 15-minute sample period.

This NIOSH recommended exposure limit of 100,000 fibers greater than 5 microns in length per cubic milliliter (0.1 fibers/cc) is intended to (1) protect against the non-carcinogenic effects of asbestos, (2) materially reduce the risk of asbestos-induced cancer (only a ban can assure protection against carcinogenic effects of asbestos) and (3) be measured by techniques that are valid, reproducible, and available to industry and official agencies.

The Occupational Safety and Health Administration establishes a permissible exposure limit of 0.2 fiber per cubic centimeter of air, determined as an 8-hour time-weighted average airborne concentration. The standards apply to all industries covered by the Occupational Safety and Health Act, including the construction and maritime industries and general industry.

VI. RESULTS

A. Missing data analysis

Workers without chest X-rays or with unreadable chest X-rays were compared with those having X-rays in order to determine if a bias affecting the work exposure/X-ray change relationship might exist.

Twenty-seven workers among those with available work histories had no or unreadable chest X-rays. While there was a difference in mean exposure months when comparing these 27 with the 477 having both readable X-rays and available work histories (Table 3a), the difference was not statistically significant at p=0.05. When comparing these same groups in terms of mean weighted average exposure, there was also no statistically significant difference. Thus, no apparent bias affecting the work exposure/X-ray relationship was likely to be due to the 27 missing or unreadable X-rays.

In assessing the potential for a bias that would affect the interpretation of the association between exposure and X-ray findings, a comparison in X-ray change outcome was made between the twenty four workers who had no available work histories and the 477 workers with both available work histories and readable chest X-rays (Table 3b). While there were differences in prevalence of both parenchymal and pleural X-ray abnormalities when comparing those having work histories with those not having histories, the differences were not statistically significant at p=0.05. Thus, it is unlikely that the study results are biased due to the 24 missing work histories.

B. Film quality - by five year intervals

X-ray film quality, assessed using the ILO scale of 1 to 4 ('4' being the worst, thus unreadable), was analyzed by five year categories beginning with the first chest X-ray taken in 1965 and ending in 1983. The analysis was conducted for two reasons: (1) to determine if any significant bias existed which was related to time of taking the X-ray; and (2) to determine if changes had occurred in the quality of radiographs available to Exxon workers.

The quality of X-rays (Table 4) remained essentially the same over the five year categories. It was noted, however, in this analysis that in films taken during the 1979 through 1983 period, 15% were of poor or unreadable film quality of (i.e. 3 or greater). This could indicate a decline in the quality of the X-rays.

C. Parenchymal X-ray abnormalities

The prevalence of parenchymal X-ray abnormalities indicative of asbestos exposure was measured initially in all those 501 workers with readable X-rays, regardless of whether work histories were available (Table 5). The overall prevalence of parenchymal profusion of '1/0' or greater was 55 of 501 (11%). As illustrated in Table 6, fifty (10%) workers had a profusion level of 1 (1/0, 1/1 or 1/2) and 5 (1%) had profusion of 2 (2/1, 2/2, or 2/3).

D. Pleural X-ray abnormalities

The prevalence of pleural X-ray abnormalities typical of asbestos exposure was initially measured also in those 501 workers with readable X-rays without respect to availability of work histories (Table 5). The overall prevalence of pleural abnormalities was 126 of 501 (25%).

When analyzed according to work/retirement status, 91 of 391 (23%) of retired workers had X-rays with pleural abnormalities evident. Thirty-five of 109 (32%) of current workers had X-rays with pleural abnormalities.

Table 7 provides a finer break down of pleural abnormalities.

One hundred and fifty-six (31%) of those with available and readable X-rays had parenchymal and/or pleural findings according to definitions stated above (Table 5).

E. Exposure-related X-ray abnormalities

To determine whether there were links between estimated dose and asbestos-associated chest X-ray abnormalities, three general approaches were taken.

1. The first approach involved a comparison among those who worked a majority of their time in different work categories (major and minor) (refer to Table 8).

a. Parenchymal X-ray abnormalities: While there is no clear prevalence trend from categories of lesser exposure to greater, two observations are of interest which show variance from this trend: (1) there was a relatively high prevalence of abnormalities in categories 'B' and 'C', particularly in minor categories 'B5' (equipment section), 'C1' (transport), and 'C2' (tank cleaners); and (2) a consistent descending gradient in prevalence is seen among minor categories within 'C', but not within 'A' or 'B.' The loss of consistency within 'B' due to 'B5' may, however, be partly due to the unique work experience of those in that minor category as is seen in the Table. In the column labeled percent time spent in 'A' (where the greatest asbestos exposure was predicted) note that those with 'usual' experience in 'B5' also spent the greatest additional exposure in major category 'A.'

b. Pleural X-ray abnormalities: Three observations are of interest: (1) there was a clear trend in the proportion of X-ray abnormalities in terms of time spent within major categories (i.e. 'A' - 35%, 'B' - 30%, 'C' - 25%); i.e., those who worked the majority of time in Category 'A' had the greatest proportion of X-ray abnormalities, 'B' next and 'C' least; and 2) as with parenchymal X-ray abnormalities, those who spent a majority of their time in minor categories 'B5', 'C1', and 'C2' had proportionally more X-ray abnormalities; and (3) a consistent descending gradient in prevalence is seen among minor categories within 'A' and 'C', but again not in 'B.' Again, the loss of consistency within 'B' due to 'B5' may be partly due to the unique work experience of those in that minor category as is seen in the Table. In the column labeled percent time spent in 'A' (where the greatest asbestos exposure was predicted) note that those with 'usual' experience in 'B5' also spent the greatest additional exposure in major category 'A.'

2. The second approach entailed tabulating the number of X-ray abnormalities for the work group in relation to varying lengths of time worked in job categories 'A' and/or 'B' and/or 'C':

a. A comparison of the number of X-ray abnormalities was made between those who EVER worked in category 'A' and those who NEVER worked in category 'A.' (refer to Table 9a)

- Parenchymal X-ray abnormalities: There was no apparent difference in the percentage of those who never worked in 'A' versus those who ever worked in 'A': 33 of 314 (11%) versus 17 of 163 (10%).

- Pleural X-ray abnormalities: There was a non-stastistically significant difference; 73 of 314 (23%) for those who never worked in 'A' versus 50 of 163 (31%) for those who ever worked in 'A.'

b. A comparison of the number of X-ray abnormalities was made between those who EVER worked in category 'B' and those who NEVER worked in categories 'A' or 'B.' (Table 9b)

- Parenchymal X-ray abnormalities: There was a difference in the percentage of those who ever worked in 'B' but not in 'A' versus those who never worked in 'A' or 'B': 33 of 303 (11%) versus 0 of 11 (0%).

- Pleural X-ray abnormalities: There was also a difference in the percentage of those who ever worked in 'B' but not in 'A' versus those who never worked in 'A' or 'B': 72 of 303 (24%) versus 1 of 11 (9%).

c. A similar comparison was made among those who worked for different lengths of time in category 'A'. (Table 10)

- Parenchymal X-ray abnormalities: No trend on the basis of increasing numbers of years of exposure in Category 'A' could be detected. For instance 13% of those working from 1 to 10 years in category 'A' had parenchymal as compared to only 8% of those working greater than 40 years.

- Pleural X-ray abnormalities: A non-stastistically significant trend on the basis of increasing numbers of years of exposure in Category 'A' was, however, detected.

d. The same kind of comparison was also made for those who worked for different lengths of time in category 'B'. (Tables 11a and 11b)

- Parenchymal X-ray abnormalities: A bimodal trend in the prevalence of X-ray abnormalities on the basis of increasing numbers of years of exposure in Category 'B' was detected. This was because of an unexpected rise in prevalence of 18% in those working from 1 to 10 years in category 'B. Further analysis of the 1 to 10 year group, as seen in Table 11b, may partly explain this variance in trend. As this table illustrates, those working from 1 to 10 years in category 'B,' having either parenchymal or pleural abnormalities, logged greater average numbers of months in 'C1' and were, in fact, the only workers with 'B' (and no 'A') experience with usual work experience in 'C1.' Also, referring to Table 8, note the relatively high prevalence of X-ray abnormalities in 'C1' (Transportation-related jobs).

- Pleural X-ray abnormalities: Again, a bimodal pattern in the prevalence of X-ray abnormalities on the basis of increasing numbers of years of exposure in Category 'B' was detected. And, again, this was because of the unique prevalence increase in those working from 1 to 10 years in category 'B. Further analysis of the 1 to 10 year group, as seen in the column labeled "Average number of months worked in 'C1'", may be responsible for this variance in trend. Referring to Table 8, note again the relatively high prevalence of pleural X-ray abnormalities in 'C1.

3. The third approach involved calculating two indexes of exposure for individuals in the study: (1) number of exposure months (EM) and (2) the weighted average exposure WAE). The EM variable can be thought of as a surrogate for cumulative exposure and the WAE variable as a surrogate for exposure intensity.

a. By exposure months (Refer to Table 12)

- Parenchymal X-ray abnormalities: The exposure months did not statistically differ when comparing those having parenchymal X-ray abnormalities with those lacking parenchymal X-ray abnormalities.

- Pleural X-ray abnormalities: Workers with pleural abnormalities had a greater mean exposure months than workers without pleural abnormalitiess. However, this result could be explained by chance (p = 0.07). Among the current worker group, there was a statistically significant difference between those with pleural X-ray abnormalities who averaged 1295.4 exposure months as compared to those without pleural X-ray abnormalities who averaged 1135.4 exposure months (p = 0.005).

b. By weighted average exposure (Refer to Tables 13 and 14)

- Parenchymal X-ray abnormalities: Table 13 illustrates that, whether looking at the entire worker group or looking at retired and current workers separately, the mean weighted average exposure did not statistically differ when comparing those with parenchymal X-ray change with those without parenchymal X-ray abnormalities. Table 14 summarizes an analysis of parenchymal X-ray abnormalities in terms of WAE stratified into four groups. No trend in increasing proportion of X-ray findings in association with belonging to a higher WAE stratum was apparent.

- Pleural X-ray abnormalities: As Table 13 illustrates, for the entire group a statistically significant difference was detected. In the entire group, those with pleural X-ray abnormalities had mean weighted average exposures of 3.008 as compared to those without pleural X-ray abnormalities with WAE's of 2.867 (p = 0.01). In the current worker group, those with pleural X-ray abnormalities had mean WAE's of 3.071 as compared to those without pleural X-ray abnormalities with WAE's of 2.75 (p = 0.016). In the retired worker group, those with pleural X-ray abnormalities had mean WAE's of 2.983 as compared to those without pleural X-ray abnormalities with WAE's of 2.896 (p = 0.137). Table 14 illustrates an analysis of pleural X-ray abnormalities in terms of WAE stratified into four groups. There is a statistically significant (p = 0.007) trend as the WAE stratum increases from 0% in the "Up to 1.50" stratum to 37% in the "Above 3.50" stratum.

VII. DISCUSSION AND CONCLUSIONS

The principle objectives in this evaluation were to (1) calculate the prevalence of asbestos-related chest X-ray abnormalities as interpreted by independent "B" readers contracted by NJDOH; and (2) investigate the relationship between historical occupational exposure of workers at Exxon and the prevalence of asbestos-related X-rays.

In this group of oil refinery and petrochemical workers chest X-ray abnormalities were present in moderate numbers, pleural abnormalities being more prevalent than parenchymal. This compares to another study by Lilis, et al. (1980) of asbestos-related X-ray abnormalities among maintenance workers in the chemical industry and in oil refinery workers. The prevalence of X-ray abnormalities was similar: 55 (11%) parenchymal abnormalities and 126 (21%) pleural abnormalities in the 501 workers evaluated in the Exxon population as compared to 34 (24%) parenchymal abnormalities and 38 (27%) pleural abnormalities in the 140 maintenance workers in the Lilis study.

As mentioned in the Background section, the Exxon-contracted "B" readers found from 1% to 7% asbestos-associated pleural abnormalities. In this NIOSH evaluation, considerably more people with X-ray abnormalities were identified.

This discrepancy in prevalence of asbestos-related radiological findings is partially attributable to differences in X-ray interpretation. The Exxon "B" readers did not use the ILO/UC system. The NIOSH readers appear to be reliable because of standardization in the reading of films.

There was no indication that the group whose X-rays were read in this evaluation was an unrepresentative one. The analysis comparing the work histories of those with X-rays to those without X-rays showed no statistically significant difference. Simlilarly, the X-ray results of twenty-four workers with no work histories did not statistically differ from those with histories.

Several analyses were conducted intended to determine whether an association between category of work and asbestos-related X-ray abnormalities existed. The starting point in this analysis was the consensus reached by the 6 person panel made up of personnel from union, management, and NJDOH. This group was handicapped by not having historical air monitoring data and having no particular expertise in deriving exposure estimates. The consensus was reached after an afternoon of discussion. Fourteen work categories were derived. Major work category 'A' was designated as the category with highest asbestos exposure, work category 'D' the lowest.

The analyses proceeded along three lines. Prevalence of asbestos-related disease was looked at in terms of: (1) work in one or more of the derived work categories; (2) duration of work at Exxon; and (3) two indexes of exposure which took account of both category or categories worked in and duration of time spent (i.e. exposure) in the work categories.

The analyses showed that chest X-ray abnormalities could be found across all work categories, both major and minor, and that, with some exceptions, there was a positive association between the length of time worked in the different categories and X-ray abnormalities. Indeed, those with limited or no history of work in 'A' also had positive X-ray findings. Even those whose usual job was in 'C' had a substantial prevalence of abnormalities. This supports the assertion that exposure at the refinery was dispersed and widespread.

Since the X-ray results indicate that exposure in some of the 'B' and 'C' categories was greater than predicted, the derived exposure indexes (EM and WAE), which were based on a linear weighting of exposure categories, are not accurate. Some individuals with lower EM and WAE probably had more asbestos exposure than the indexes indicated. Therefore, differences observed between groups using WAE and EM probably are underestimates of an asbestos effect.

The most serious implication of this evaluation is the overall prognosis for disease in both previous and current Exxon workers. While the level of exposure to asbestos necessary to increase the risk of incurring asbestos-related disease was inexactly estimated, studies of a number of other occupations and industries indicate an increased risk of cancers that will result from past exposures to asbestos.

Reports by Bittersohl (1971) and by Bittersohl and Ose (1971) called attention to asbestos hazards in the chemical industry. Twenty-six cases of mesothelioma had been observed over a period of four years (1967-1971); this was in sharp contrast to the extreme rarity of this type of malignancy in the preceding period. Twenty-two patients had worked in a large chemical industry (Leuna), two in another chemical plant (Buna) and one in a foundry. The only female patient alluded to in the report had had no occupational exposure to asbestos, but was the wife of a worker at the Leuna plant. Only 16 patients had had direct occupational exposure to asbestos, while nine had had indirect exposure (working in areas where asbestos was occasionally handled by other workers); in one case there was only a history of household exposure. Chest X-ray films taken before the development of mesothelioma were available in 23 cases; in 17, pleural thickening and pleural plaques were present.

It has been estimated that chemical plant and oil refinery maintenance workers have 0.15 the risk of asbestos-related cancer as compared to insulation workers (Nicholson 1982), a relatively small but, real risk.

The risk of lung cancer and mesothelioma thus appears to be a real concern for Exxon workers since accumulated experience indicates that low-level asbestos exposure (which includes indirect occupational, neighborhood or household exposure) is sufficient to result in a significant risk of developing mesothelioma and other cancers (Harries et al., 1960 and Selikoff, 1977). The conduction of a standardized mortality ratio (SMR) study should be considered with both company and union cooperation and support. The SMR study should be of individuals whose chest X-rays were reviewed by the NJDOH. This study would better characterize the risk of developing cancer among individuals with asbestos-related X-ray changes. Mortality experience would be compared between individuals with and without X-ray changes. Such a study would be greatly facilitated by the follow up work that has already been completed by N. Hanis and co-workers (1985). Many of the death certificates have already been obtained for this smaller group which was included in the much larger study by Hanis.

On the other hand, the higher prevalence of pleural abnormalities as compared to parenchymal small irregular opacities and the fact that the parenchymal abnormalities were not very advanced, indicate that the risk for disabling asbestosis is less with this type of asbestos exposure.

In this study, X-rays were read using a strict interpretation of the ILO/UC system. This leads the "B" reader to report abnormalities as consistent with asbestos-related disease even when alternative explanations - such as extrapleural fat or muscle shadows - are possible. The system is intended primarily as an epidemiologic tool for the study of large groups and is not a substitute for individualized reading of the X-rays and consideration of additional information (e.g. body weight) in individual workers. Populations with similar prevalence of X-ray findings based on the ILO/UC system have increased asbestos-related mortality whether or not every X-ray change consistent with asbestos exposure was actually caused by asbestos exposure. The standard level of practice is to use the ILO/UC classification when interpreting X-rays for asbestos-related changes. This standard classification allows managers and industrial hygienists to judge the relative prevalence of X-ray changes as compared to other working groups. It eliminates as much as possible the biases and quirks of X-ray interpretation by different doctors at different times.

VI. RECOMMENDATIONS

A. Industrial Hygiene

Because the evaluation was primarily a radiographic survey, the industrial hygiene recommendations are included only for general reference.

1. Workplace controls and practices

Unless a less toxic chemical can be substituted for a hazardous substance, engineering controls are normally the most effective way of reducing exposure. The best protection is enclosing operations and/or providing local exhaust ventilation at the site of asbestos release. Isolating operations can also reduce exposure. Using respirators or protective equipment is less effective than the controls mentioned above, but is sometimes necessary.

In addition, the following controls are recommended:

a. Specific engineering controls are required for asbestos by OSHA. Refer to the OSHA Standard: 1910.1001. Also refer to the NIOSH criteria document: Occupational Exposure to Asbestos #77169.

b. Substitute the less toxic mineral wool and fibrous glass for asbestos where possible. Many other substitutes are also available.

c. There are extensive recommended and required engineering and procedural regulations for construction and repair projects involving asbestos material. Before disturbing any asbestos containing materials you must be properly trained and you must follow the required guidelines.

Good work practices can help to reduce hazardous exposures. The following work practices are recommended:

a. Workers whose clothing has been contaminated by asbestos must change into clean clothing.

b. Do not take contaminated work clothes home. Family members could be exposed.

c. Contaminated, disposable work clothes should be disposed of with asbestos.

d. Wash any areas of the body that may have contacted asbestos at the end of each work day, whether or not known skin contact has occurred.

e. Do not eat, smoke, or drink where asbestos is handled, processed, or stored, since the chemical can be swallowed. Wash hands carefully before eating or smoking.

f. Ongoing asbestos abatement projects in sealed areas become very hot and humid. There is a risk of heat stress. You should be trained by your employer to recognize the warning signs and the proper action to take to avoid serious dangerous working conditions.

g. Do not dry sweep for cleanup. Use a vacuum or a wet method to reduce dust during cleanup.

h. When vacuuming, a high efficiency particulate absolute (HEPA) filter should be used, not a standard shop vacuum.

2. Personal protective equipment

Workplace controls are better than personal protective equipment. However, for some jobs (such as outside work, confined space entry, jobs done only once in a while, or jobs done while workplace controls are being installed), personal protective equipment may be appropriate.

The following recommendations are only guidelines and may not apply to every situation.

a. Clothing

i. Avoid skin contact with asbestos. Wear disposable protective gloves and clothing. Safety equipment suppliers/manufacturers can provide recommendations on the most protective glove/clothing material for your operation.

ii. All protective clothing (suits, gloves, footwear, headgear) should be clean, available each day, and put on before work.

iii. TYVEK is recommended as a most effective material for protective disposable clothing.

b. Respiratory Protection

i. Improper use of respirators is dangerous. Such equipment should only be used if the employer has a written program that takes into account workplace conditions, requirements for worker training, respirator fit testing, and medical exams, as described in OSHA 1910.134.

ii. Asbestos is a known human carcinogen, therefore, for the absolute best protection, at any exposure level, use an MSHA/NIOSH approved supplied air respirator with a full facepiece operated in the positive pressure mode or with a full facepiece, hood, or helmet in the continuous flow mode, or use an MSHA/ NIOSH approved selfcontained breathing apparatus with a full facepiece operated in pressuredemand or other positive pressure mode.

iii. However, during asbestos abatement projects when it is impossible to use supplied air or self contained breathing apparatus, use a full facepiece powered air purifying respirator with high efficient particulate filters.

3. Handling and storage

Prior to working with asbestos you should be trained on its proper handling and storage.

A regulated, marked area should be established where asbestos is handled, used, or stored.

Airborne asbestos dust is very difficult to remove. It is therefore essential that any area where asbestos is handled be enclosed and isolated. The material should be kept wet with special surfactants and water.

Enclose operations and use local exhaust ventilation with negative pressure air filtration and high efficiency particulate filters in areas of asbestos removal. If enclosure with containment "glove" bags is not used for minor repairs, respirators must be worn and proper procedures must be followed.

All asbestos materials must be removed and disposed of according to regulations. The area must be monitored to ensure airborne asbestos levels are below limits prior to reoccupation of the area where asbestos was disturbed.

B. Medical

Before beginning employment and at regular times after that, the following are recommended:

1. Lung function tests (annually)

2. Chest X-rays should be considered every year beginning 10 years after exposure.

3. Any evaluation should include a careful history of past and present symptoms with an exam. Medical tests that look for damage already done are not a substitute for controlling exposure.

4. The worker should request copies of his/her medical testing. The worker has a legal right to this information under OSHA 1910.20.

5. As regards mixed exposures, because smoking can cause heart disease, as well as lung cancer, emphysema, and other respiratory problems, it may worsen respiratory conditions caused by chemical exposure. Even if the worker has smoked for a long time, stopping now will reduce your risk of developing health problems. The risk of lung cancer may be as much as 92 times higher for people with asbestos exposure who smoke than for those without both exposures.

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available, upon request, from NIOSH, Division of Technical Services, Information Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through National Technical Information Service (NITS), Springfield,. Virginia 22161.

Copies of this report have been sent to:

1. Exxon Company U.S.A., P.O. 222, Linden NJ 07036
2. Requestors of this study.
3. NIOSH Region II
4. U.S. Department of Labor, OSHA, Region II

For the purpose of informing the 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 calender days.

APPENDIX A - ILO Classification system

For the purposes of this evaluation, three components of the ILO classification system were employed: (1) that part dealing with small opacities within the lungs (parenchymal asbestosis); (2) that part relating to thickening of pleural surfaces or pleural plaques); and (3) pleural calcification.

As regards small opacities in the lungs, three parameters were considered:

(1) profusion, whether irregular (as in the case of asbestos)) or rounded (as in the case of silicosis).

Under profusion there are four categories:

Category 0 - small irregular or rounded opacities absent or less profuse than in category 1.

Category 1 - small irregular or rounded opacities definitely present but relatively sparse. The normal lung markings are usually visible.

Category 2 - small irregular or rounded opacities numerous. The normal lung markings are usually partly obscured.

Category 3 - small iregular or rounded opacities very numerous. The normal lung markings are usually totally obscured.

(2) type of opacity: p, q, or r (as in silicosis) or s, t, or u (as in asbestosis):

s - fine irregular or linear opacities

t - medium irregular opacities

u - coarse (blotchy) irregular opacities

(3) Extent of disease in the upper, middle, and lower lung zones.

As regards disease of the pleural lining of the lungs, four parameters were considered:

(1) Site of disease: costophrenic angle, diaphragm, chest walls and whether present on the left, right or on both sides of the chest.

(2) Width grades A, B, and C

Width A - maximum width up to about 5 mm.

Width B - maximum width over about 5 mm and up to about 10 mm.

Width C - maximum width over about 10 mm.

(3) Extent grades 1 to 3

Grade 1 - total length equivalent to up to one quarter of the projection of the lateral chest wall.

Grade 2 - total length exceeding one quarter but not one half of the projection of the lateral chest wall.

Grade 3 - total length exceeding one half of the projection of the lateral chest wall.

(4) Type - circumscribed and/or diffuse pleural disease.

As regards pleural calcification, site and grade were considered. Grading was according to the following guidelines:

(1) Site: Chest wall, diaphragm, and other including the mediastinal and pericardial pleura.

(2) Grade

Grade 0 - no pleural calcification

Grade 1 - one or more areas of pleural calcification, the sum of whose greatest diameters does not exceed 2 cm.

Grade 2 - one or more areas of pleural calcification, the sum of whose greatest diameters exceeds 2 cm but not 10 cm.

Grade 3 - one or more areas of pleural calcification the sum of whose greatest diameters exceeds 10 cm.

TABLE 1 - JOB CLASSIFICATIONS - EXXON REFINERY AND CHEMICAL PLANT - BAYWAY

A1	Insulator
A2*	Pipe fitter, boiler maker
B1	Building section (masons, painters, carpenters, etc.)
B2	Other metal section (welders, rigger, etc.)
B3	Laborer pre-1966)
B4	Process production, operators
B5	Equipment section (machinist, electricians, instruments, technicians)
B6	Crane operator
B7	Tube cleaners
C1	Transportation, other (truckers, forklift drivers, heavy equipment)
C2	Tank cleaners
C2	Process, tank field
C3	Storehouse
C4	Dispatchers, janitors, yard service, laborer post-1966
C4	Receiving, packing and shipping
C4	Security
D1	Miscellaneous, non-classifiable workers

* Jobs are ranked within letter categories

TABLE 2 DESCRIPTION OF COHORT

Original Data Set	550
	-20 Number not meeting eligibility of >= 20 years
	530
	-17 Number with unreadable X-ray (Quality '4')
	513
	-12 Number with no Xray
Number with readable X-ray and eligible	501
	-24 Number with no work history
Number with readable X-ray, work history, and eligible	477*

* - includes 105 current workers and 372 retired workers as of December, 1980

TABLE 3a MISSING DATA ANALYSIS - COMPARISON OF EXPOSURE MONTHS AND WEIGHTED AVERAGE EXPOSURE OF THOSE WITH X-RAYS VERSUS THOSE WITHOUT X-RAYS

	n	Mean EM	Mean WAE
X-rays (readable)	477	1209	2.9
No X-rays (or unreadable)	27	1253	2.9
TOTAL =	530	p = 0.44	p = 0.55

TABLE 3b MISSING DATA ANALYSIS - COMPARISON OF DISEASE PREVALENCE OF THOSE WITH WORK HISTORIES COMPARED TO THOSE WITH WORK NO HISTORIES

	n	Parenchymal Disease	Pleural Disease on X-ray
Work Histories	477	50 (10%)	123 (26%)
No Work Histories	24	5 (21%)	3 (12%)
TOTAL =	501	p = 0.11 (Fisher's)	p = 0.22 (ChiSq)

TABLE 4 FILM QUALITY BY FIVE YEAR CATEGORIES*

	QUALITY			
	1	2	3	4
1965 THROUGH 1968	17 (19%)	57 (61%)	13 (13%)	5 (5%)
1969 THROUGH 1973	20 (17%)	79 (69%)	10 (8%)	4 (3%)
1974 THROUGH 1978	23 (19%)	85 (72%)	7 (5%)	2 (1%)
1979 THROUGH 1983	25 (12%)	148 (71%)	27 (13%)	6 (2%)

* INCLUDING THOSE WITH NO WORK HISTORIES

TABLE 5 INDIVIDUALS WITH ABNORMALITIES*

	Parenchymal	Pleural	Both	Either	Negative
CURRENT (109)	7 (6%)	35 (32%)	5 (4%)	37 (34%)	72 (66%)
RETIRED (392)	48 (12%)	91 (23%)	20 (5%)	119 (31%)	273 (69%)
TOTAL (501)	55 (11%)	126 (25%)	25 (5%)	156 (31%)	345 (69%)

* Total = 501 eligible

TABLE 6 PROFUSION OF SMALL PARENCHYMAL OPACITIES: DISTRIBUTION

	0/1 or less	1/0	1/1	1/2	2/1	2/2	2/3	3/3	Any Abn. 1/0 or >
Number	446	33	13	4	1	2	2	0	55
Percentage	89%	6.6%	2.6%	0.8%	0.2%	0.4%	0.4%	0.0%	11%

TABLE 7 - PLEURAL ABNORMALITIES*

	NUMBER (PERCENTAGE) OF THOSE WITH X-RAYS
Any Pleural Abnormality	126 (25%)
Bilateral Abnormality	98 (20%)
Unilateral Abnormality	28 (5%)
Width A**	77 (15%)
Width B**	24 (5%)
Width C**	18 (2%)
Circumscribed	24 (4%)
Diffuse	4 (1%)
Circumscribed and Diffuse	7 (1%)
Calcification	23 (4%)
Costophrenic Angle (bilat.)	26 (5%)
Diaphragm	20 (3%)

* n = 501

** refers to highest width attained

TABLE 8 ABNORMALITIES BY USUAL MAJOR AND MINOR CATEGORY

Exposure Category	Number	% Time in 'A'	Parenchymal	Pleural	Either
A1	10		1 (10%)	7 (70%)	7 (70%)
A2	80		7 (8.8%)	26 (32%)	28 (35%)
TOTAL A	90		8 (9%)	33 (37%)	35 (39%)
B1	45	0%	6 (13%)	18 (40%)	19 (42%)
B2	52	5%	5 (10%)	14 (27%)	18 (35%)
B3	12	0%	1 (8%)	2 (17%)	2 (17%)
B4	100	5%	8 (8%)	12 (12%)	20 (20%)
B5	84	15%	10 (11%)	23 (27%)	29 (34%)
B6	0	0%	0 (0%)	0 (0%)	0 (0%)
B7	5	0%	0 (0%)	0 (0%)	0 (0%)
TOTAL B	298		30 (10%)	69 (23%)	88 (30%)
C1	24		5 (21%)	9 (37%)	10 (42%)
C2	27		4 (15%)	8 (30%)	10 (37%)
C3	9		1 (11%)	1 (11%)	2 (22%)
C4	22		2 (9%)	3 (14%)	5 (23%)
TOTAL C	82		12 (14%)	21 (25%)	27 (32%)
D1	7		0 (0%)	0 (0%)	0 (0%)
TOTAL	477 (100%)		50 (10.5%)	123 (25.8%)	150 (31.4%)

TABLE 9a PARENCHYMAL AND PLEURAL DISEASE IN TERMS OF WORK IN CATEGORY 'A'

	TOTAL	PARENCHYMAL	PLEURAL	EITHER
EVER 'A'	163	17 (10%)	50 (31%)	58 (36%)
NEVER 'A'	314	33 (11%)	73 (23%)	92 (29%)
	477	p = 0.9*	p = 0.1*	p = 0.19*

TABLE 9b PARENCHYMAL AND PLEURAL DISEASE IN TERMS OF WORK IN CATEGORY 'B'

	TOTAL	PARENCHYMAL	PLEURAL	EITHER
EVER 'B'	303	33 (11%)	72 (24%)	91 (30%)
NEVER 'A' or 'B'	11	0 (0%)	1 (9%)	1 (9%)
	314	p = 0.29**	p = 0.23**	p = 0.12**

* Chi Square
** Fisher's Exact Test

TABLE 10 X-RAY ABNORMALITIES IN TERMS OF DURATION OF EXPOSURE IN CATEGORY 'A'

	TOTAL	PARENCHYMAL	PLEURAL	EITHER
< 1 YEAR	314	33 (10%)	73(23%)	92 (29%)
1 TO 10 YEARS	62	8 (13%)	14 (22%)	19 (30%)
11 TO 20 YEARS	25	3 (12%)	8 (32%)	10 (40%)
21 TO 30 YEARS	35	2 (6%)	11 (31%)	11 (31%)
> 30 YEARS	41	4 (8%)	17 (41%)	18 (43%)
	477	$p = 0.84^*$	$p = 0.09^*$	$p = 0.34^*$

* Chi square for trend

TABLE 11a - X-RAY ABNORMALITIES IN TERMS OF DURATION OF EXPOSURE IN CATEGORY 'B' WITH NO EXPOSURE IN CATEGORY 'A'

	TOTAL	PARENCHYMAL ABNORMALITIES	PLEURAL ABNORMALITIES	EITHER
< 1 YEAR	11	0 (0%)	1 (9%)	1 (9%)
1 TO 10 YEARS	44	8 (18%)	13 (29%)	17 (38%)
11 TO 20 YEARS	28	2 (7%)	4 (14%)	5 (17%)
21 TO 30 YEARS	72	5 (6%)	14 (19%)	18 (25%)
31 TO 40 YEARS	143	15 (10%)	36 (25%)	44 (30%)
> 40 YEARS	16	3 (23%)	5 (31%)	7 (43%)

TABLE 11b - CONTRIBUTION OF 'C1' EXPERIENCE TO PREVALENCE OF X-RAY ABNORMALITIES IN THOSE WITH 1 TO 10 YEARS EXPERIENCE IN WORK CATEGORY 'B'

	PARENCHYMAL ABNORMALITIES		PLEURAL ABNORMALITIES	
	Avg. # Mos. in C1	Proportion with usual work in C1	Avg. # Mos. in C1	Proportion with usual work in C1
< 1 YEAR	74.7	0	0.0	0
1 TO 10 YEARS	148.4	5/8 (40%)	240.8	9/13 (69%)
11 TO 20 YEARS	36.2	0	51.5	0
21 TO 30 YEARS	3.7	0	8.7	0
31 TO 40 YEARS	1.7	0	3.0	0
> 40 YEARS	0.0	0	0.0	0

TABLE 12 COMPARISON OF THOSE WITH AND THOSE WITHOUT X-RAY ABNORMALITIES IN TERMS OF NUMBER OF EXPOSURE MONTHS

	Parenchymal		Pleural	
	#	EM	#	EM
With Abnormality	50	1210.3	123	1247.2
Without Abnormality	427	1206.1	354	1194.9
	p = 0.92		p = 0.07	

TABLE 13 COMPARISON OF THOSE WITH AND THOSE WITHOUT X-RAY ABNORMALITIES IN TERMS OF WEIGHTED AVERAGE EXPOSURE

	Parenchymal		Pleural	
	#	WAE	#	WAE
With Abnormality	50	2.847	123	3.008
Without Abnormality	427	2.909	354	2.867
	p = 0.42		p = 0.01	

TABLE 14 PARENCHYMAL AND PLEURAL DISEASE IN TERMS OF WEIGHTED AVERAGE EXPOSURE CATEGORIES

WAE	n	PARENCHYMAL	PLEURAL
UP TO 1.50	12	0 (0%)	0 (0%)
1.51 TO 2.50	85	11 (13%)	21 (24%)
2.51 TO 3.50	309	34 (11%)	75 (24%)
ABOVE 3.50	71	5 (7%)	27 (37%)

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