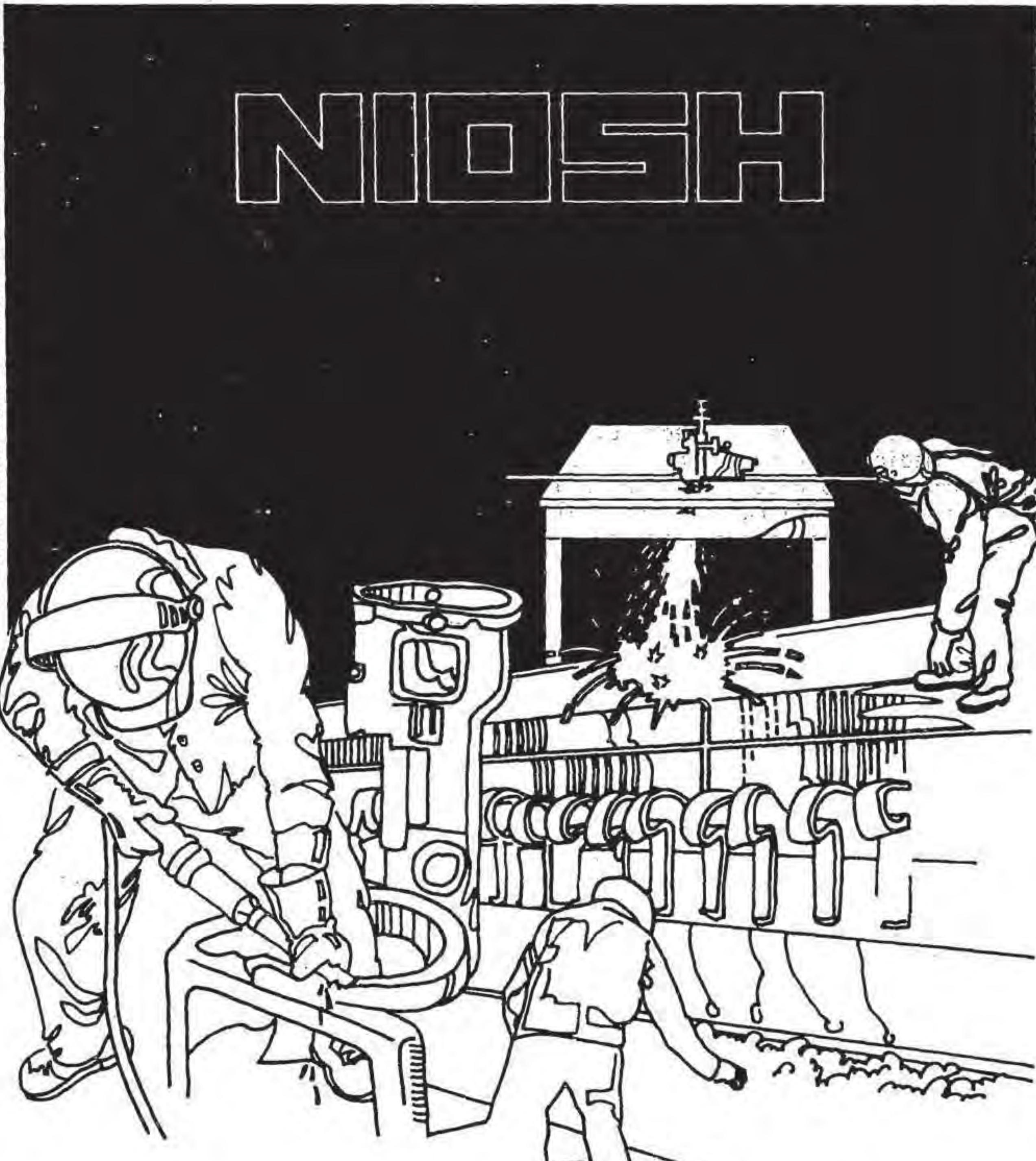
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health




# Health Hazard Evaluation Report

HETA 81-357-1321
ELKEM METALS COMPANY
ALLOY, WEST VIRGINIA

## 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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ELKEM METALS COMPANY
ALLOY, WEST VIRGINIA

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## I. SUMMARY

On July 15, 1981, the National Institute for Occupational Safety and Health (NIOSH) received a request to evaluate the possible excess incidence of cancer and heart disease among employees at the Elkem Metals Company, Alloy, West Virginia.

In December, 1981, NIOSH investigators conducted an initial walk-through survey. This was succeeded by a proportional mortality ratio (PMR) study and a reading of 86 sets of chest X-rays (taken by the company) to screen for pneumoconiosis. On July 26-30, 1982, NIOSH conducted a combined environmental and medical evaluation at the Elkem plant. In the environmental portion of the evaluation, employees from the furnace department, packing department, mix house, and steam plant were monitored for potential exposures to airborne respirable particulates, crystalline silica, amorphous silica, silicon metal, arsenic, and fly ash. The medical evaluation consisted of respiratory questionnaires and pulmonary function tests on 93 randomly selected workers. Serial chest X-rays were read by a licensed "B" reader on 86 current Elkem workers. A proportional mortality ratio (PMR) study was constructed to evaluate cause of death in 373 former Elkem workers who died between 1966 and 1980.

Silica concentrations for 15 personal air samples ranged from non-detectable (less than 0.030 milligrams per sample) up to 0.233 mg/m$^3$. Four of these samples were in excess of the NIOSH recommended standard of 0.050 mg/m$^3$ and included samples from the mix unloader, potlining ladleman, and the steam plant equipment attendant. None of these four samples exceeded the calculated OSHA standard. Respirable particulate levels for thirteen personal air samples obtained from furnacemen and tappers ranged from 0.01 to 0.39 mg/m$^3$. These air levels are well below the OSHA dust standard of 5.0 mg/m$^3$. Arsenic concentrations for four samples obtained furnace tappers were non-detectable (less than 0.0003 mg/sample). Respirable silicon particulate levels for workers in the packing and crushing areas were no higher than 1.01 mg/m$^3$, about 20% of the OSHA nuisance dust standard. Respirable amorphous silica levels for air samples obtained from two dust collector mechanics were 0.27 and 2.24 mg/m$^3$. The ACGIH TLV for amorphous silica is 3.0 mg/m$^3$. For all substances monitored the levels obtained represent potential exposures since workers wore dust respirators. Overall dust levels were generally lower than reported in previous company environmental data and may reflect decreased production at the time of the NIOSH survey.

Results for the questionnaire showed a high prevalence (32%) of chronic bronchitis in the current workforce. These were few abnormalities in pulmonary function. Age and smoking, but not dust exposure, were associated with a deterioration in pulmonary function. Evidence of pneumoconiosis was found on the X-rays of 4 of 86 workers. The PMR results showed a statistically significant elevation in deaths from chronic obstructive pulmonary disease (COPD) and COR pulmonale (PMR 148 and 187), when compared to the United States' general population.

Based on the radiologic and environmental results, NIOSH concludes that Elkem workers have had hazardous exposures to excess concentrations of crystalline silica. A potential health hazard from silica exposures continues to exist in selected plant areas. Elkem workers appear to be at an elevated risk of dying from non-malignant respiratory disease and of developing chronic bronchitis. Neither deterioration in pulmonary function nor prevalence of chronic bronchitis in current workers could be statistically related to past dust exposure. Recommendations to reduce free silica exposure are presented in Section VIII of this report.

KEYWORDS: SIC 3313 (Electrometallurgical Products), silicon metal and alloys, silicon dioxide, crystalline silica, amorphous silica, fly ash, arsenic, pulmonary function tests, chronic obstructive lung disease, chronic bronchitis, proportional mortality ratio.

## II. INTRODUCTION

On July 15, 1981, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation from an authorized representative of Local 3-89 of the Oil, Chemical and Atomic Workers Union (OCAW) to evaluate mortality rates from cancer and heart disease and the risk of adverse health effects from in-plant dust exposures at Elkem Metals Company, Alloy, West Virginia. An initial walk-through survey was conducted by a NIOSH physician and industrial hygienist on December 21-22, 1981. An interviewer-directed screening questionnaire was administered to twenty workmen, selected without randomization but from a representative variety of work areas.

A Proportional Mortality Ratio (PMR) study of deceased members of the Elkem work force was then completed and included in Interim Report #1, which was sent out in April 1982. Eighty-six sets of chest films were read in order to detect evidence of pneumoconiosis. Confidential notification of results was mailed to each employee on July 21, 1982.

On the basis of the medical results and review of company environmental data, a follow-up survey was undertaken. It included a respiratory questionnaire and pulmonary function tests on 93 people. The environmental evaluation consisted of assessing worker exposure to respirable particulates, crystalline silica, amorphous silica, silicon metal, arsenic, and fly ash. Environmental findings were reported in Interim Report #2, distributed in January 1983.

## III. BACKGROUND

### A. Plant Description

The Elkem plant is a 45 year old facility which principally produces silicon metal, ferrosilicon alloys, and calcium silicon alloys. Secondary products are zirconium and strontium silicon alloys. Ferromanganese, silicomanganese, aluminum and ferrochromium alloys have been produced in the recent past and vanadium alloys have been produced in the more distant past. The products being made during the followup survey included silicon metal and calcium silicon alloys.

The Elkem Metals Company purchased the Union Carbide Metals Division, taking control of the Alloy plant in July 1981. The corporate industrial hygiene department, health and safety protocols, and plant management were carried over intact from Union Carbide.

### B. Process Description

The furnaces are of the submerged electric arc type and are chiefly powered by hydroelectric power with supplementation from an on-grounds steam plant. Raw materials including quartz, coal, wood chips, lime, barites, and scrap steel are charged via a tram system from a physically separate mix house. The mix is melted at high temperature and periodically the molten metal is tapped into ladles or "pots", which are lined with either a silica sand-clay or a graphite-clay mixture. The molten metal is then poured into "chills" and cooled. The final slablike product is crushed and sized, then either stored or shipped. There is also a packing process, although most of the finished metals are shipped unpackaged by rail or truck.

C. Hygiene and Medical Surveillance

The Elkem industrial hygiene program was adopted intact from Union Carbide. The staff includes a full-time environmental engineer and a part-time assistant. Environmental sampling and analysis are performed by the company; the results are compiled on a semi-annual basis. During 1981, personal air sampling was conducted for total and respirable particulates and respirable crystalline silica. In previous years, workers had been monitored for coal tar pitch volatiles, carbon monoxide, and various metals, including manganese, chromium, lead, and arsenic. The curtailment of these broader assays parallels the elimination of ferromanganese, silico-manganese, aluminum and ferrochromium alloy production.

Elkem maintains a mandatory respirator program which outlines, for each hazardous operation, specific approved respirators to be used by employees.

The Elkem medical program, like the industrial hygiene program, follows that of Union Carbide. There is a full-time industrial nurse and a physician who attends on a regular basis. Physical exams and laboratory tests are performed at the time of employment and follow-up is on the following basis:

| AGE | SCHEDULE |
|---|---|
| over 50 | yearly |
| 36-50 | every two years |
| under 36 | every three years |

Pulmonary function tests have been introduced within the past two years and are interpreted by the plant physician. The general plan is to repeat them at 5-year intervals. Periodic chest x-rays have been obtained for over forty years and are also interpreted by the plant physician. Films with suspicous findings are sent out for a radiologists interpretation.

## IV. EVALUATION DESIGN AND METHODS

A. Environmental

Environmental sampling was conducted during first shift production and maintenance activities on July 27-29, 1982. Personal and/or general area air samples were collected from the furnace department (buildings

3 and 8), packing department (buildings 3, 6, 7 and 8), mixhouse, and steam plant. Workers were monitored for determination of exposures to respirable particulates, crystalline silica, amorphous silica, silicon metal, arsenic, and fly ash. The air sampling and analytical methodologies for the different types of air samples are shown in Table I. Personal air sampling devices were attached to the workers' lapels and represent potential exposures since the workers wore dust respirators during the workshift.

Furnace department workers include furnacemen, tappers, and ladlemen. They were evaluated for potential exposure to respirable particulates, crystalline silica, and arsenic. Thirteen respirable particulate samples were collected from the furnacemen and tappers. Four of the 13 samples were analyzed for crystalline silica. Because crystalline silica was not present in measurable quantities, the remaining nine personal samples were not analyzed. Three respirable dust samples were obtained from the ladlemen, and two general air samples were collected from the pot lining area. These five samples were analyzed for crystalline silica.

Silicon metal and calcium silicon alloys contain small quantities of arsenic. As a result, air samples for arsenic determination were obtained from four furnace tappers. Furnace tappers were selected since they appeared to be potentially the most exposed group in the furnace department. Four general area air samples were collected in the immediate area of the furnace and, for background comparison, were also collected outdoors at locations remote to the active furnaces.

Packing department employees were evaluated for potential exposure to silicon metal particulates generated during crushing and packing operations. Respirable dust samples were collected from 10 employees, including a crusher, a cleaner, crane operators, packers, and a screen tester. Paired general area air samples for respirable and total particulates were collected at the C6 cleaner machine and the screen test area of the C7 crusher machine to determine the relative concentration of the respirable and non-respirable particulate fractions in these areas. In addition, four of the 12 respirable dust samples were screened for the presence of crystalline silica.

Mixhouse workers, including the mix unloader and mix dispatcher, were potentially exposed to dusts generated during transfer and unloading of raw materials. Two respirable dust samples were collected from each worker, and one air sample was collected in the general area of the mix dispatcher. All samples were analyzed for crystalline silica.

Steam plant workers were evaluated for potential exposure to fly ash and crystalline silica. Three respirable dust samples were collected, one each from the boiler operator, equipment attendant, and maintenance mechanic. A bulk sample of fly ash was collected and analyzed for crystalline silica.

Dust collector mechanics were potentially exposed to airborne particulates while performing maintenance work on the dust collectors. Respirable dust samples were obtained from two mechanics and analyzed for amorphous silica. Bulk samples of dust collector particulate, one each from the #3 and #15 dust collectors, were collected and analyzed for amorphous and crystalline silica.

B. Medical

1. Cross-sectional Analysis

On December 21-22, 1981, during the initial survey, an interviewer - administered medical screening questionnaire was given to twenty Elkem workers. Workers were selected by the NIOSH physician from the current seniority list as a representative sample from all age groups and work sites but without statistical randomization. Questions were directed towards obtaining information on present and previous occupational experience, medical history and habits, and current general medical symptoms, with particular attention to respiratory symptoms.

Following the initial visit, 86 sets of chest films from current workers were read by a NIOSH contract "B" reader to detect pneumoconiosis in the Elkem work force. Films were selected on the basis of seniority with at least ten years of plant experience as a pre-requisite for inclusion. Particular job categories were selected consistent with estimations of greatest exposure to free silica based on the NIOSH walk-through investigation and Elkem's environmental monitoring. Four serial chest X-ray films, including the intact earliest and most recent filming were read for each worker to evaluate any progression in lung lesions and opacities and to control for lung disease that was pre-existent or emerging at the time of employment. Films were interpreted according to the ILO/VC system for pneumoconioses (4).

Pulmonary function tests (PFT) and respiratory questionnaires were administered to a random sample of the Elkem workforce during the NIOSH follow-up investigation, July 26-30, 1982. A random sample of 93 men was selected using a random number table and the most current seniority lists of 457 workers. Because of recent plant lay-offs, this was an actual 30% sample of the active workforce. The respiratory questionnaire was interviewer administered and was directed towards the evaluation of present and previous occupational history; the assessment of respiratory, particularly pulmonary symptoms; and current general medical status. Questions were based on the standard American Thoracic Society (ATS) questionnaire, amended to incorporate exposure and background questions specific to Elkem. Pulmonary function tests were performed with an Ohio Medical Model # 880 Spirometer using the prediction equation derived from Knudsen et. al. (5).

Forced vital capacity (FVC), one-second forced expiratory volume (FEV 1), and one-second forced expiratory volume percent (FEV 1%) were examined using univariate and multivariate techniques. The terminology of pulmonary function testing is explained in Appendix I. Criteria for a valid test are presented in Appendix IA.

PFT results were analysed by analysis of variance, using age, height, smoking history, plant employment tenure and a cumulative measure of exposure as independent variables. Plant years were taken from the employee history, but were not validated by plant employment records. Smoking pack years are a multiple of the average daily numbers of packs smoked times the total number of years smoked. That is 30 cigarettes (1.5 packs) smoked a day for 10 years would amount to 15 personal pack years (PPY). Cumulative dust years are a multiple of milligrams of environmental total dust concentration in a given year and of the total number of years worked -- that is, of lifetime in-plant dust exposure. Dust levels for individual job titles and years were calculated from Union Carbide environmental data taken between 1972-81. As a comparable example, a man who worked for ten years -- 5 of them in a job category with a mean dust level of 5.0 mg/m3 and 5 of them where the mean dust level was 1.0 mg/m3 -- would have a cumulative dust exposure of 30 mg/m3-years. An explanation of the method follows in Appendix 2.

At the request of the plant medical department, the most recent set of Elkem's own pulmonary function tests were evaluated in order to determine whether there was a systematic discrepancy between the NIOSH results and Elkem's own tests.

Medical questionnaires were analyzed to determine cumulative symptom frequencies and to examine the association between various exposure factors and severity of symptoms. A logistic regression analysis was applied with either shortness of breath or chronic bronchitis as a dependent varible and age, pack-years and dust-years as independent variables. Chronic bronchitis was defined by the presence of: a productive cough on at least 4 days a week and for three months a year, lasting at last 2 years. Chronic cough was defined using the same criteria, except that it included non-productive cough. Shortness of breath was defined as symptomatic if observed with hill climbing or rapid walking and severe if capacity was less than that of peers while walking on level ground.

In order to determine the effect of various biological and environmental factors on a population with recognized pulmonary disease, all workers with clinical chronic obstructive pulmonary disease (see Appendix I), were compared to the normal plant population for the following factors: age, pack-years and dust-years.

2. Mortality Studies

A proportional mortality ratio (PMR) study of deaths was conducted among active, disabled and retired workers, for deaths between 1966-80. The study utilized insurance records and was limited to deaths among workers aged 44 years and older in order to control for deficiencies in death benefit records among younger workers. The company personnel office supplied death information, copied from death certificated on active, disabled and retired employees from 1961-1981. This information is maintained as part of a requisite company life insurance program. By limiting the study to workers aged 44 years and older, younger short-term employees who might have transferred insurance policies to another souce can be eliminated, and therefore a source of underreporting of deaths can be excluded.

Based on the death records of 373 deceased workers evaluated in the PMR, a case control study compared workers who died from pulmonary disease with a 3:1 random sample of workers who died from non-pulmonary causes. Independent variables included age at death, years worked for Union Carbide, and a dichotomous division of deceased workers based on jobs with greater and lesser dust exposure. In general, exposure determinations paralleled inside or outside work assignments as indicated by job title and department. Where a job catgory was ambiguous, available environmental records were consulted. For example, all furnace, cleaning and packing, steam plant, and maintenance jobs were considered inside work. Warehouse, office and janitorial work are inside but not exposed jobs, however, because environmental records indicated a low level of dust exposure. In a reciprocal classification, traffic department jobs were usually considered outside and less exposed, except as in the case of crusher-operators, where environmental records indicated a high exposure.

## 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 solely 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.

Table 2 summarizes the environmental criteria for sampled substances along with a brief description of their primary health effects. The following discussion pertains to crystalline silica since exposure levels were found to be in excess of the NIOSH recommended standard.

The principle adverse health effect of crystalline silica is the dust related respiratory disease silicosis, a fibrotic condition of the lungs. A variety of immunological abnormalities, most likely related to lung injury have also been described (6).

Crystalline silica, usually referred to as free silica, is defined as silicon dioxide ($SiO_2$) molecules arranged in a fixed pattern as opposed to a nonperiodic, random molecular arrangement defined as amorphous silica. The three most common crystalline forms of free silica encountered in industry are quartz, tridymite, and cristobalite, with quartz being by far the most common of these. NIOSH, in its recommendations for a free silica standard, has proposed that exposures to all forms of free silica be controlled so that no worker is exposed to respirable airborne concentrations greater than 0.05 $mg/m^3$, as averaged over a 10-hour working day, 40-hour work week. This recommendation was designed to protect workers from silicosis. Exposures to free silica greater than one-half the recommended standard, or "action level", should initiate adherence to the environmental, medical, labeling, recordkeeping, and worker protection guidelines contained in the NIOSH criteria document, "Occupational

Exposure to Crystalline Silica" (6). The current federal, or OSHA standard for respirable free silica exposure is an 8-hour time-weighted average based upon the 1968 ACGIH TLV formula of 10 $mg/m^3$ divided by the percent $SiO_2$ plus 2 ($10 mg/m^3/\%SiO_2 + 2$) for respirable quartz. One-half this amount was established as the limit for cristobalite and tridymite. As can be seen from the calculation, the OSHA regulation is based on the percentage of free silica contained in the respirable particulate exposure, whereas the NIOSH recommended standard applies directly to the airborne concentrations of respirable free silica.

## VI. RESULTS AND DISCUSSION

### A. Environmental

A summary of the environmental sampling data is presented in Table 3. Sampling results for the various contaminants are presented by plant location in Appendices 3-7.

#### 1. Furnace Department

Results of the air samples collected from the furnacemen and tappers indicate that, at the time of the evaluation, respirable particulate and crystalline silica concentrations were well within the exposure guidelines (Appendix 3). Respirable particulate levels were generally low, ranging from 0.01 to 0.47 $mg/m^3$ (average 0.21 $mg/m^3$). Of the three samples collected from the ladlemen for silica determination, two were nondetectable, with respirable dust levels of 0.25 and 0.38 $mg/m^3$. These two samples were taken from ladlemen who were primarily engaged in slag removal and other duties where the potential for silica exposure was minimal. The third sample was reported at 0.065 $mg/m^3$, or approximately 130% of the NIOSH recommended standard of 0.050 $mg/m^3$. This sample, in contrast to the other two, was obtained from a ladleman who spray-lined ladles with a silica sand/clay mixture. Fourteen percent of the particulate weight for this sample consisted of crystalline silica. In this instance, the OSHA PEL would be 0.63 $mg/m^3$ (10 $mg/m^3$ divided by $\%SiO_2+2$), about 10 times higher than the measured level. Both general area air samples did not contain detectable quantities of crystalline silica, with dust concentrations reported at 0.05 and 0.15 $mg/m^3$. The air sample obtained in C3F indicated that the dust produced by the spray lining operation was mainly confined to the immediate vicinity of the ladleman.

All of the personal and general area air samples collected for arsenic were below the environmental limit of detection (less than 0.0005 $mg/m^3$).

2. Packing Department

Environmental samples obtained from packing department employees showed respirable silicon particulate concentrations ranging from 0.08 to 1.01 $mg/m^3$, averaging approximately 0.34 $mg/m^3$ (Appendix 4). In the area of the cleaner machine the total particulate level was measured at 0.92 $mg/m^3$ while the respirable fraction was measured at 0.21 $mg/m^3$. In the screen test area of the C7 crusher machine the total particulate and respirable fractions were measured at 1.59 and 0.28 $mg/m^3$, respectively. These values suggest that approximately 20% of the airborne dust in these areas is respirable. In addition, the total dust levels measured in the immediate area of the cleaner machine and crusher machine were at the lower end of the range of dust concentrations reported in Union Carbide's environmental monitoring records for similar samples obtained during calendar year 1981. This may reflect depressed production at the time of the NIOSH study, as only two furnaces were in operation.

The four air samples analyzed for crystalline silica were nondetectable and, as a result, the dust levels reported above are comparable to the threshold limit value (TLV) for nuisance particulates - 5.0 $mg/m^3$ for respirable particulates and 10.0 $mg/m^3$ for total particulates.

3. Mixhouse

One of two respirable dust samples obtained from the mix dispatchers contained detectable levels of crystalline silica, reported at a concentration of 0.043 $mg/m^3$ (Appendix 5). Of significance were the results of the two air samples collected from the head mix unloader indicating excessive crystalline silica concentrations of 0.131 and 0.223 $mg/m^3$, about 2 1/2 to 4 1/2 times higher than the NIOSH recommended standard. Both samples were below their respective calculated OSHA PELs of 0.20 and 0.40 $mg/m^3$. The silica concentration for the general area air sample was reported at 0.032 $mg/m^3$. All four samples where crystalline silica was detected were in excess of the action level (one-half of the NIOSH recommended standard), the level at which engineering and/or administrative controls should be instituted.

4. Steam Plant

Air sampling results for steam plant employees are presented in Appendix 6. Crystalline silica was detected in one of two air samples (one sample was lost during analysis), at a concentration of 0.051 $mg/m^3$. This sample, obtained from the equipment attendant, is equivalent to the NIOSH criterion but represents only about 11% of the calculated OSHA PEL of 0.45 $mg/m^3$ based on a quartz content of 20%. Fly ash concentrations averaged 0.16 $mg/m^3$ (range: 0.10 - 0.25 $mg/m^3$). These concentrations were below the OSHA standard of 5.0 $mg/m^3$. The bulk sample of fly ash contained about 6% crystalline silica; no cristobalite was detected (less than 1.5%).

5. Dust Collectors

Qualitative X-ray diffraction results indicated that both bulk samples of dust collector dust were composed of amorphous materials; no crystalline silica was detected. The sample from #3 dust collector contained up to 89% amorphous silica and some potassium and calcium, probably in the form of oxides. The other dust sample, from dust collector #15, contained mostly amorphous silica (up to 61%), calcium, iron, potassium and sulfur, again probably in the form of oxides.

The two personal samples obtained from the dust collector mechanics were measured at 0.27 and 2.24 $mg/m^3$ (Appendix 7). Assumming that the particulate in these samples mostly contains amorphous silica it would be prudent to apply the ACGIH recommended criterion of 3 $mg/m^3$ for respirable amorphous silica.

B. Medical -- Cross-sectional

1. Screening Questionnaire

Results from the initial medical questionnaire indicated that shortness of breath and cough were highly prevalent and that cigarette smoking alone could not account for the frequency of shortness of breath or cough. It was on the basis of these findings and an apparent elevated mortality from pulmonary disease (see below), that a further assessment of pulmonary function was considered warranted.

2. Radiographic Analysis for Pneumoconiosis

Eighty-six sets of chest films from current Elkem employees were assembled and interpreted by a qualified "B" reader*. There were three diagnoses of pneumoconiosis -- ILO/UC classification q 1/0 -- and one additional case suggestive of pneumoconiosis -- ILO/UC classification q 0/1. Workers with pneumoconiosis were employed in the furnace, steam plant and maintenance departments. All workers had greater than 10 years of seniority at Elkem/Carbide; none had radiologic evidence of dust disease on the initial chest film in their series. The date of the initial film was usually identical with date of hiring, except where radiograph deterioration precluded an interpretation of the initial film.

In addition to the findings of pneumoconiosis, an asbestos plaque was observed in one worker and other abnormalities, unrelated to dust, were reported in five workers.

Of 160 x-rays taken between 1975-82, the NIOSH reader found that 79 (49%) were of poor or unreadable quality. Elkem management and the Oil, Chemical and Atomic Workers were informed of this result.

* A "B" reader is a physician specifically trained and licensed to interpret and codify environmental dust diseases on the basis of chest x-ray.

### 3. Respiratory Questionnaire -- Follow-up Study

Respiratory questionnaires were completed on 93 Elkem workers (Table 4). Forty-three men (46%) had symptoms at a chronic cough, and 30 (32%) satisfied the case definitions for chronic bronchitis. Severe shortness of breath and bronchospasm were less frequently reported -- 10.8% and 9.7%, respectively.

Smoking history among Elkem workers was as follows: 15 workers were non-smokers, 48 were current smokers and 30 were former smokers, having stopped smoking six or more months prior to the NIOSH study. The average total consumption was 24 PPY for the entire workforce, including current, former and non-smokers. The range included 0-100 pack years. Thirty-three percent (31 men) of the interviewed group had smoked fewer than 10 pack years; eighteen of these men had never smoked. Thirty-one men (33%) had accrued thirty or more pack years.

The prevalence of chronic bronchitis (32%) represents an approximate two-fold increase, when compared to some normal populations (11). There were no significant associations between the variables of age, pack-years, and dust-years and chronic bronchitis, chronic cough or shortness of breath. Age approached statistical significance for shortness of breath ($p<.10$), as did smoking for chronic cough ($p<.15$) and chronic bronchitis ($p<.10$), but neither was significant at the .05 level (Table 5).

Because prior exposures could influence current respiratory symptoms, there was extensive questioning about prior work history, particularly at worksites other than Union Carbide. Prior work that was considered to involve a possible previous dust exposure included: mining, quarrying, rock drilling and tunneling, work in a cotton mill, sandblasting and foundry work. Only one member of the study group reported working more than two years cumulatively in any of these jobs, and no one had worked more than 5 years. No one had worked more than one year in a non-Carbide dusty job after 1950. For these reasons, dust exposures from other occupational sources were not considered to be significant confounding issues.

### 4. Pulmonary Function Testing

Pulmonary function tests were performed on 86 of 93 men (Table 6). Seven were excluded because of concurrent respiratory infections or recent use of bronchial medications.

Different statistical models for age, height, plant years, smoking, and dust-years showed age and plant years to be multicollinear. That is, a given worker's age and seniority were consistent to the point of being statistically interchangeable (Table 7). Because multicollinearity was not observed between age, height, smoking and dust-years, and because the statistical models were no worse, when plant years were excluded, this variable was eliminated from further analytical consideration.

Multivariate analysis, also called multiple regression analysis is a means to assess the contributed role of different factors such as age, height, smoking, etc., on a single effect such as pulmonary functon. Multivariate analysis (Table 8) showed age to be significantly associated with a loss in $FEV_1$ and FVC but not FEV 1%. Pack years were not significantly associated with loss of $FEV^1$ and $FEV_1\%$. Dust years were not statistically associated with volume changes.

In Table 9, chronic obstructive pulmonary disease (COPD) is examined among cases and non-cases according to age, smoking history and dust-years. COPD was defined using the following criterion:

| AGE | Normal FEV 1% |
|---|---|
| <30 | >72% |
| 30-59 | >69% |
| >60 | >64% |

Age and smoking are strongly associated with COPD, whereas dust exposure is not, although it approaches statistical significance ($p<15\%$). Nevertheless cumulative dust exposures among Elkem workers with COPD are 32% greater than among workers who are not affected. Although age and smoking are more strongly associated with COPD and increased age is associated with increased total dust exposure, independent of any association between dust and COPD, it is a suggestive trend.

In addition to the previous age related scale for COPD, there is a standard clinical definition for restrictive lung disease (RLD), which is an FVC of <80% of predicted. On the basis of these empirical divisions, 13 workers (15%) had obstructive pulmonary disease, 4 (5%) had restrictive disease, and 4 (5%) had mixed obstructive and restrictive disease.

In the Knudsen prediction equations, smokers are excluded. It is therefore noteworthy that although 75% of Elkem workers had a past or current smoking history, the group FVC was 97% and the FEV 1 was 93% of predicted, when compared to the Knudsen non-smoking normals (Table 6). Either baseline pulmonary function among Elkem workers may have been superior to the Knudsen reference population, or possibly there may have been a significant drop-out from employment of workers with inferior pulmonary performance, ie., people at the lower end of the scale who couldn't do the work.

One of the unusual characteristics of the Elkem population is that in terms of age and plant-year experience, workers fall into two distinct groups (see Table 10). Of 88 workers who completed questionnaire data, 54 fell into an older age group (50-66) with a median age of 56. Thirty-four workers were in the younger age group (range 28-42) with a median age of 32. This 10 year gap in employment reflects a lack of hiring in the 1950's, given a stable and aging post-war population and a gradually decreasing total plant work force. It is interesting that the yearly loss of volume in FEV 1 among younger workers exceeds that of the older workers (0.06 to 0.04), an observation which is in general contradiction with normal pulmonary function parameters (14).

The Elkem medical department requested that the NIOSH pulmonary function tests results be compared with recent Elkem tests on the same individuals. There were 88 workers for whom NIOSH tests could be matched with an equivalent Elkem test, taken within 12 months of the NIOSH test. There was concurrence in 56 of 88 tests (64%). However, Elkem tended to report larger volumes for both FEV 1 and FVC than NIOSH with a greater proportion increase in the FVC. The result was a smaller $FEV_1$/FVC ratio so that COPD was diagnosed more frequently -- 29 cases out of 88 workers (33%). Because the volumes were larger, inadequate inspiration or technician error are unlikely explanations for the comparative differences. The differences are most likely due to machine in accuracy or to a biological difference related to season.

5. Mortality Studies

A Proportional Mortality Ratio (PMR) study of deaths among active, disabled and retired workers, inclusive of the years 1966-80, is reported on Table 11. Although the proportional rate of death for several types of cancer, including lung and large intestine, are greater than for the general population, these elevations are not statistically significant. There is, however, a statistically significant excess representation of deaths from respiratory disease, particularly from chronic obstructive lung disease (COPD) and cor pulmonale, which have a PMR of 148 and 187, respectively. An issue of appropriate comparison arises, since pulmonary death rates are elevated in general for West Virginia inhabitants. In 1970 United States death rates for pneumonia and influenza and for COPD were 30.9/100,000 and 15.2/100,000, respectively, but in West Virginia they were 43.9/100,000 and 22.8/100,000. If West Virginia death rates were used, for comparison, the proportion of deaths from respiratory causes among Elkem workers would not be elevated. Although several specific cancers, such as sarcomas among the retirees, may appear to be dangerously elevated, because of the small numbers involved, no statistical inferences have been made where under five cases have been observed. Mortality from heart disease was not elevated above expected.

In Table 12, results are presented from a case control study comparing age at death and number of years employed by Union Carbide for 30 workers who died of respiratory causes and 97 workers who died of other causes. In a case control mortality study, people who died with a particular condition are compared to other people who died from other causes, to see if there is some significant difference between the two groups, in order to shed light on the cause of death. Workers who died from pulmonary causes had statistically fewer years of employment (22.06 vs. 25.29 years) but there was no significant difference in age at death. Twenty three of the men (77%) who died of pulmonary disease had worked in dusty areas; whereas 64 men (69.1%) who died of non-pulmonary causes worked in dusty areas. This difference is not statistically significant.

## VII. SUMMARY AND CONCLUSIONS

The investigations which we undertook in this hazard evaluation were intended to evaluate the nature and causes of a high prevalence of respiratory complaints observed on the screening questionnaire and to evaluate reports of elevated mortality rates.

The findings of excess levels of airborne silica coupled with the detection of pneumoconiosis in 4 of 86 workers underlines the persistence of silica as a continued occupational hazard in the industrial environment (6,17). It is noteworthy that the three areas identified by NIOSH as potential sources of exposure -- ladle lining, the boiler room and the mixhouse -- were the only areas with levels exceeding the NIOSH recommended standard.

The identification by questionnaire of 30 cases (32% of workers) of chronic bronchitis suggests a level of disease in excess of the usual rate observed in similar workplaces (11). There are several mechanisms by which dust has been implicated in the etiology of pulmonary infection and insult (18,19). In the present study, neither estimated comulative dust exposure nor cumulative smoking could account for the high prevalence of bronchitis.

The elevated proportion of pulmonary related deaths indicated by the PMR has no satisfactory explanation. It may be accounted for by a factor such as the tendency of local doctors to ascribe primary cause of death to pulmonary disease, when a man is known to work in a dusty trade. On the other hand, pulmonary deaths are generally reduced among working populations because of a selection at an early age against men with a limited work capacity due to respiratory impairment.

It should also be noted that the PMR is a sensitive tool for detecting unusual proportions of death, particularly from cancer. Although lung cancer deaths were not elevated statistically, they were elevated numerically above the expected. This is of particular concern, given the past presence of arsenic -- a well described cause of lung cancer -- at levels several times above the NIOSH recommended standard (15,16).

## VIII. RECOMMENDATIONS

1. Authorize "B" reading of chest X-rays on the full workforce from the furnace, steam plant and and mix-house areas; continue this practice on all subsequent films on workers from these areas. Men with findings of pneumoconiosis should be transferred to a less exposed area of the plant, unless silica exposures can be reduced below the NIOSH recommended standard.

2. Where feasible, crystalline silica exposures should be maintained below the NIOSH recommended standard of 0.050 mg/M$^3$ through implementation of engineering and/or administrative controls. Continued use of respiratory protection should be regarded as an interim control measure.

3. To adequately assess the health hazards associated with jobs that involve contact with fly ash and/or coal dust, air samples obtained by the company from steam plant employees should be analyzed for crystalline silica.

4. Warning signs should be posted at areas where potential excessive exposure to fly ash or coal dust containing free silica exists.

5. An education program should be established whereby workers are provided information on health hazards associated with the various substances encountered in the workplace with special attention on silica.

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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. Elkem Metals Company
2. Confidential Requestor
3. OCAW, Local 3-89
4. NIOSH, Region III
5. OSHA, Region III

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 1

Sampling and Analysis Methodology

Elkem Metals Company
Alloy, West Virginia
HETA 81-357

July 27-29, 1982

| Substance | Collection Device | Flow Rate (Lpm) | Duration (hrs) | Analysis | Detection Limit mg/sample | Reference |
|---|---|---|---|---|---|---|
| Crystalline Silica (respirable) | PVC filter with 10mm cyclone* | 1.7 | 6-8 | X-ray diffraction | 0.03 | 1 |
| | PVC filter with 1/2 inch cyclone** | 9.0 | 5-7 | X-ray diffraction | 0.03 | 1 |
| Silicon Metal (respirable) | PVC filter with 10mm cyclone | 1.7 | 6-8 | Gravimetric | 0.01 | 2 |
| Silicon Metal (total) | PVC filter | 1.5 | 7-8 | Gravimetric | 0.01 | 2 |
| Arsenic | Sodium carbonate impregnated cellulose ester filter | 1.5 or 2.0 | 7-8 | Atomic Absorption | 0.0003 | 3 |
| Fly Ash (respirable) | PVC filter with 10mm cyclone | 1.7 | 5-6 | Gravimetric | 0.01 | 2 |
| Amorphous Silica (respirable) | PVC filter with 10mm cyclone | 1.7 | 7-8 | Gravimetric | 0.01 | 2 |

* personal sampling
** area sampling

TABLE 2

Evaluation Criteria

Elkem Metals Company
Alloy, West Virginia
HETA 81-357

| Substance | Evaluation Criteria* ($mg/m^3$) NIOSH | OSHA | ACGIH | Primary Health Effects | Reference |
|---|---|---|---|---|---|
| Crystalline Silica (respirable) | 0.050 | 10 $mg/m^3$ divided by % $SiO_2$ + 2 | 10 $mg/m^3$ divided by % $SiO_2$ + 2 | Silicosis: a pneumoconiosis due to the inhalation of silicon dioxide containing dust, which is a disabling, progressive, and sometimes fatal pulmonary fibrosis characterized by the presence of nodulation in the lungs. | 6,7,8 |
| Silicon Metal | | | | | |
| (respirable) | - | 5.0 | 5.0 | Regulated as nuisance particulate. Excessive concentrations of nuisance particulates may cause unpleasant deposits in the eyes, ears, and nasal passages, and may seriously reduce workroom visibility. | 7 |
| (total) | - | 5.0 | 10.0 | | |
| Fly Ash (respirable) | | 5.0 | 5.0 | Same as above | 7 |
| Amorphous Silica (respirable) | - | - | 3.0 | Amorphous silica has been shown to cause fibrosis and significantly decreased lung function in monkeys. | 9 |
| Arsenic | 0.002 | 0.010 | 0.200 | Arsenic compounds are irritants of the skin (mucous membranes and eyes; arsenical dermatoses and epidermal carcinoma are reported risks of exposure to arsenic compounds, as are other forms of cancer. | 7,8,10 |

* NIOSH criteria represent time-weighted averages (TWA) for up to a 10-hour workday; OSHA standards and ACGIH threshold limit values (TLV) are TWA's based on an 8-hour workday.

TABLE 3

Summary of Exposures*

Elkem Metals Company
Alloy, West Virginia
HETA 81-357

July 27-29, 1982

| Department/ Location | Job Classification or Area | Respirable Crystalline Silica $mg/m^3$ | Respirable Particulate $mg/m^3$ | Silicon Metal $mg/m^3$ | Total Arsenic $mg/m^3$ | Respirable Fly Ash $mg/m^3$ | Respirable Amorphous Silica $mg/m^3$ |
|---|---|---|---|---|---|---|---|
| Furnace | Furnaceman[1] | ND(2)<br>- | 0.18(7)<br>0.01-0.39 | | | | |
| Furnace | Furnace Area | | | | ND(2)<br>- | | |
| Furnace | Tapper[2] | ND(2)<br>- | 0.25(6)<br>0.14-0.38 | | ND(4)<br>- | | |
| Furnace | Ladleman | 0.022(3)<br>ND-0.065 | 0.36(3)<br>0.25-0.46 | | | | |
| Furnace | Ladlelining Area | ND(2)<br>- | 0.10(2)<br>0.05,0.15 | | | | |
| Packing | Crusher Operator | | | 0.22(2)R<br>0.10,0.33 | | | |
| Packing | Cleaner Operator | | | 0.17(2)R<br>0.08,0.27 | | | |

(continued)

TABLE 3 (continued)

| Department/ Location | Job Classification or Area | Respirable Crystalline Silica mg/m3 | Respirable Particulate mg/m3 | Silicon Metal mg/m3 | Total Arsenic mg/m3 | Respirable Fly Ash mg/m3 | Respirable Amorphous Silica mg/m3 |
|---|---|---|---|---|---|---|---|
| Packing | Cleaner Machine | | | 0.21(1)R<br>-<br>0.92(1)T<br>- | | | |
| Packing | Packer[3] | | | 0.49(3)R<br>0.31-0.80 | | | |
| Packing | Crane Operator | | | 0.23(2)R<br>0.17,0.30 | | | |
| Packing | Screen Tester | | | 1.01(1)R<br>- | | | |
| Packing | Screen Test Area | | | 0.28(1)R<br>-<br>1.59(1)T<br>- | | | |
| Mix | Mix Dispatcher | 0.021(2)<br>ND,0.043 | 0.30(2)<br>0.28,0.32 | | | | |
| Mix | Skip Hoist Area | 0.032(1)<br>- | 0.14(1)<br>- | | | | |
| Mix | Head Mix Unloader | 0.177(2)<br>0.131,0.223 | 0.63(2)<br>0.28,0.98 | | | | |
| Steam Plant | Boiler Operator | ND(1)<br>- | | | | 0.10(1)<br>- | |

(continued)

TABLE 3 (continued)

| Department/ Location | Job Classification or Area | Respirable Crystalline Silica mg/m$^3$ | Respirable Particulate mg/m$^3$ | Silicon Metal mg/m$^3$ | Total Arsenic mg/m$^3$ | Respirable Fly Ash mg/m$^3$ | Respirable Amorphous Silica mg/m$^3$ |
|---|---|---|---|---|---|---|---|
| Steam Plant | Equipment Attendant | 0.051(1)<br>- | | | | 0.25(1)<br>- | |
| Steam Plant | Boiler Mechanic | <br>- | | | | 0.12(1)<br>- | |
| Maintenance | Dust Collector Mechanic | | | | | | 1.26(2)<br>0.27,2.24 |

* Values are presented in the following order: mean, number of samples analyzed (in parenthesis), and range
ND - none detected; mg/m$^3$ - milligrams of substance per cubic meter of air
1 includes head furnacemen and furnacemen
2 includes head tapper and tapper
3 includes packer and cleaner packer
R - respirable dust sample; T - total dust sample

TABLE 4

Symptom Frequency

Elkem Metals Company
Alloy, West Virginia
HETA 81-357

| Symptom of Condition | Number Reporting Symptom | Frequency (%) |
|---|---|---|
| Chronic Cough* | 43 | 46.2 |
| Chronic Bronchitis* | 30 | 32.3 |
| Symptomatic Shortness of Breath* | 23 | 24.7 |
| Severe Shortness of Breath* | 10 | 10.8 |
| Frequent Bronchospasm** | 9 | 9.7 |

* See text (page 7) for definition
** Shortness of breath with wheezing, greater than 10 times per year
n = 93

TABLE 5

Logistic Regression Analysis of Respiratory Illness

Elkem Metals Company
Alloy, West Virginia
HETA 81-357

| Illness | Age | | Smoking Pack-Year | | Dust Year | |
|---|---|---|---|---|---|---|
| | $X^2$(a) | P-Value(b) | $X^2$ | P-Value | $X^2$ | P-Value |
| Shortness of Breath[1] | 4.85 | 0.0883 | 0.13 | 0.9361 | 0.36 | 0.8372 |
| Chronic Bronchitis/Cough[2] | 1.53 | 0.4644 | 4.46 | 0.1077 | 0.74 | 2.6910 |
| Chronic Bronchitis[3] | 0.17 | 0.6775 | 3.05 | 0.0816 | 0.79 | 0.3728 |

1 = Shortness of Breath (SOB) had 3 possible responses: normal, SOB while walking on level ground or up a hill, or SOB while walking with people of his own age.

2 = Chronic Cough had 2 responses: chronic productive cough and phlegm or chronic non-productive cough.

3 = Chronic Bronchitis only.

NOTE: Chronic bronchitis is defined as a cough with phlegm for the past 2 years during 3 or more months per year, 4 or more times per week.

a = $X^2$ stands for Chi-Square, which is a test of statistical significance.

b = P-Value measures the likelihood of a result being due to chance. Generally, a P-Value of <5% (.05) is used to indicate statistical significance.

TABLE 6

Descriptive Statistics for Pulmonary Function Tests

Elkem Metals Company
Alloy, West Virginia
HETA 81-357

| Variable | Respondents | Mean | Standard Deviation | Range | Distribution (Normal=Gaussian) |
|---|---|---|---|---|---|
| Age | 93 | 47.2 | 11.67 | 28-66 | Not Normal |
| Height (Inches) | 91 | 68.6 | 2.67 | 60-74 | Not Normal |
| Pack Year | 93 | 24.2 | 22.70 | 0-100 | Not Normal |
| Plant Year | 93 | 22.3 | 10.30 | 8-40 | Not Normal |
| Dust Year | 93 | 112.9 | 87.06 | 6.5-452.1 | Not Normal |
| $FEV_1$ (Liters) | 86 | 3.7 | 0.79 | 1.47-5.1 | Normal |
| FVC (Liters) | 86 | 4.3 | 0.84 | 2.49-6.16 | Normal |
| $FEV_1$/FVC (%) | 86 | 76.7 | 7.45 | 54-90 | Not Normal |
| Residual* $FEV_1$ (Liters) | 86 | -0.2 | 0.52 | -1.8-0.87 | Normal |
| Residual* FVC (Liters) | 86 | 0.1 | 0.57 | -1.38-1.13 | Normal |
| Residual* $FEV_1$/FVC (Liters) | 86 | -2.8 | 7.16 | -24.97-9.36 | Not Normal |
| Percent Predicted $FEV_1$ | 86 | 93.45 | 15.06 | 48-122 | Normal |
| Percent Predicted FVC | 86 | 97.0 | 13.10 | 67-132 | Normal |

* Residual here means the difference between measured and predicted values.

TABLE 7

Models for Regression Analysis Involving Age, Height, Work, Dust, and Smoking

Elkem Metals Company
Alloy, West Virginia
HETA 81-357

| | $FEV_1$ | | FVC | | $FEV_1$/FVC (%) | |
|---|---|---|---|---|---|---|
| Independent Variables | Corr. Coef. ($R^2$) | P-Value | Corr. Coef. ($R^2$) | P-Value | Corr. Coef. ($R^2$) | P-Value |
| I. A, H, P, D, C | 0.62 | 0.001 | 0.56 | 0.0001 | 0.50 | 0.0001 |
| II. A, H, P, D* | 0.62 | 0.001 | 0.56 | 0.0001 | 0.50 | 0.0001 |
| III. A, H, S, D | 0.61 | 0.001 | 0.55 | 0.0001 | 0.42 | 0.0001 |

* Best model for this study.

A = age; H = height; P = pack years; D = dust years; S = smoking (1 = never smoked, 2 = exsmoker; 3 = current smoker); C = plant years.

TABLE 8

Results of Multivariate[a] Regression Analyses
for Observed Pulmonary Function Values

Elkem Metals Company
Alloy, West Virginia
HETA 81-357

| Pulmonary Function | Statistics | Age | Height | Pack Year | Dust Year | Significance of Model |
|---|---|---|---|---|---|---|
| $FEV_1$ (Liters) | b[1] | 0.0355 | 0.1295 | -0.0066 | 0.0005 | |
| | Sb[2] | 0.0064 | 0.0202 | 0.0027 | 0.0008 | |
| | p | 0.0001 | 0.0001 | 0.0189 | 0.5066 | 0.0001 |
| | $R^2$ | | | | | 0.6216 |
| FVC (Liters) | b | -0.0379 | 0.1498 | -0.0023 | 0.0005 | |
| | Sb | 0.0074 | 0.0233 | 0.0032 | 0.0009 | |
| | p | 0.0001 | 0.0001 | 0.4694 | 0.5677 | 0.0001 |
| | $R^2$ | | | | | 0.5559 |
| $FEV_1$/FVC (%) | b | -0.1359 | 0.3403 | -0.1214 | 0.0038 | |
| | Sb | 0.0842 | 0.2659 | 0.0365 | 0.0099 | |
| | p | 0.1104 | 0.2042 | 0.0013 | 0.7017 | 0.0001 |
| | $R^2$ | | | | | 0.2636 |

1 b = regression coefficient
2 Sb = standard error of the regression

a Multivariate regression is a means to assess the contributed role of different factors such as age, height, smoking, etc., on a single effect such as pulmonary function.

TABLE 9

Analysis of Chronic Obstructive Pulmonary Disease (COPD)

Elkem Metals Company
Alloy, West Virginia
HETA 81-357

| Independent Variable | Symptom | Number | Mean | Standard Deviation | Range | Probability |
|---|---|---|---|---|---|---|
| Age | + COPD | 16 | 55.00 | 5.87 | 35-60 | <0.0001 |
| | - COPD | 72 | 46.22 | 11.86 | 28-66 | |
| Pack Year | + COPD | 16 | 44.38 | 19.36 | 2-84 | <0.0001 |
| | - COPD | 72 | 19.79 | 20.31 | 0-100 | |
| Dust Year | + COPD | 16 | 142.01 | 71.41 | 26.4-226.4 | <0.15 |
| | - COPD | 72 | 108.70 | 91.55 | 6.5-452.1 | |

TABLE 10

Characteristics of Older and Younger Workforce

Elkem Metals Company
Alloy, West Virginia
HETA 81-357

| | Younger Group | Older Group |
|---|---|---|
| Number of People | 34 | 54 |
| Age - Range | 28-42 | 50-66 |
| Median Age | 32 | 56 |
| Plant Years | 11.6 | 31.2 |
| Dust Years (Range) | 12.2-111.1 | 6.5-452.1 |
| Dust Years (Mean) | 48.0 | 156.7 |
| $FEV_1$ Lost/Year (Liters) | 0.06 | 0.04 |

TABLE 11

PMR of Deaths Among Employees Over Age 44
For the Years 1966-80

Elkem Metals Company
Alloy, West Virginia
HETA 81-357

| Cause of Death | Observed Deaths | Expected Deaths | PMR |
|---|---|---|---|
| Malignant Neoplasm | 84 | 75.659 | 111 |
| All GI Cancer | 23 | 21.104 | 109 |
| Colon | 9 | 6.905 | 130 |
| Stomach | 5 | 3.770 | 133 |
| Pancreas | 5 | 4.463 | 112 |
| Lung | 32 | 25.433 | 126 |
| Soft tissue and bone | 3 | 0.583 | 515 |
| Circulatory Diseases | 201 | 210.684 | 95 |
| Ischemic Heart Disease | 150 | 154.719 | 97 |
| Cerebrovascular Disease | 39 | 29.522 | 132 |
| Pulmonary Diseases | 37 | 25.009 | 148* |
| COPD/Cor pulmonale | 20 | 10.715 | 187** |
| Pneumonia | 11 | 8.885 | 124 |
| Gastrointestinal Diseases | 11 | 17.010 | 65 |
| Accidents | 19 | 19.947 | 95 |
| Other | 21 | 24.624 | 85 |
| | 373 | 373.00 | 100 |

* Significant at the 0.05 level: Poisson Distribution
** Significant at the 0.01 level: Poisson Distribution

Expected Deaths are calculated from 5-year intervals from the 1970 U.S. (white male) national death rates.

TABLE 12

Case Control Analysis of Respiratory Mortality

Elkem Metals Company
Alloy, West Virginia
HETA 81-357

| | Number | Plant Years | Probability | Age at Death | Probability |
|---|---|---|---|---|---|
| Respiratory Death | 30 | 22.1±86.2 | | 66.0±10.2 | |
| | | | <0.05 | | >.70 |
| Non-Respiratory Death | 97 | 25.3±85.3 | | 66.9±9.1 | |

Power test for 3:1 sample

Assumption:

| | |
|---|---|
| Relative Risk | 3.0 |
| Disease Prevalence | 0.50 |
| Power | 0.662 |

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