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Industrial Hygiene Survey of Lone Star Cement Co.

Nazareth, Pennsylvania

Cement Workers Morbidity Study

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Environmental Investigations Branch
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16. Abstract (Limit: 200 words) As part of the Cement Workers Morbidity Study, an industrial hygiene survey was conducted at the Lone Star Cement Company in Nazareth, Pennsylvania. Environmental sampling was conducted to determine the presence and concentration of various contaminants. For most jobs at this site the levels of respirable and total dust were below the permissible limits. One sample for a mill helper exceeded ACGIH recommended levels for respirable nuisance particulate (5mg/m3). Total dust samples for a maintenance worker and a packer exceeded the MSHA 10mg/m3 standard for nuisance dust. Eight respirable dust samples contained detectable levels of quartz (14808607), and three exceeded the MSHA permissible exposure limit. The authors recommend that measures be taken to reduce exposures, including the use of ventilation systems, personal protective equipment, and improving clean up procedures.

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Executive Summary

The Lone Star Cement Plant in Nazareth, Pennsylvania was surveyed by a NIOSH team of industrial hygienists, on March 11 and 12, 1982. Samples were collected and analyzed for respirable and total dust, free crystalline silica, aluminum, cobalt, magnesium, manganese, nickel, other trace elements, asbestos and nitrogen dioxide.

The respirable dust levels for most jobs are below recommended exposure levels. However, one sample from a mill helper exceeded the ACGIH recommended level of 5.0 mg/m^3 for respirable nuisance particulate. Two total dust samples worn by a packer and a maintenance worker exceeded the MSHA standard of 10 mg/m^3 for nuisance dust. Of the dust contaminants measured, only quartz is considered to be present in excessive concentrations. Exposure to quartz was observed in association with raw materials, clinker, and masonry cement. Three respirable dust samples exceeded the MSHA-PEL for respirable quartz.

Introduction

The National Institute for Occupational Safety and Health (NIOSH) has undertaken a study to determine the effects of materials found in Portland Cement facilities on the human respiratory system. A representative group of plants in the United States has been randomly chosen for inclusion in this study. Lone Star Cement in Nazareth, Pennsylvania was the sixteenth of sixteen plants to be surveyed.

Each plant survey consisted of:

1. Medical testing of employees to determine the prevalence of respiratory disease.

2. Environmental sampling to determine the presence and concentration of various contaminants.

Medical and environmental testing were not done during the same week.

This report deals with the environmental aspect of the study. The environmental surveys are primarily concerned with the composition and concentration of airborne dust particles. It is important to characterize the presence of toxic contaminants as completely as possible, so that, if respiratory problems are discovered, the proper contaminant may be implicated as the cause of disease. Therefore, toxic gases and metals are also monitored. A major weakness of much of the past medical research of worker populations in Portland cement plants is the lack of complete documentation of the respiratory hazards to which workers are exposed. For these reasons, comprehensive industrial hygiene surveys are a very important aspect of the Cement Workers Morbidity Study.

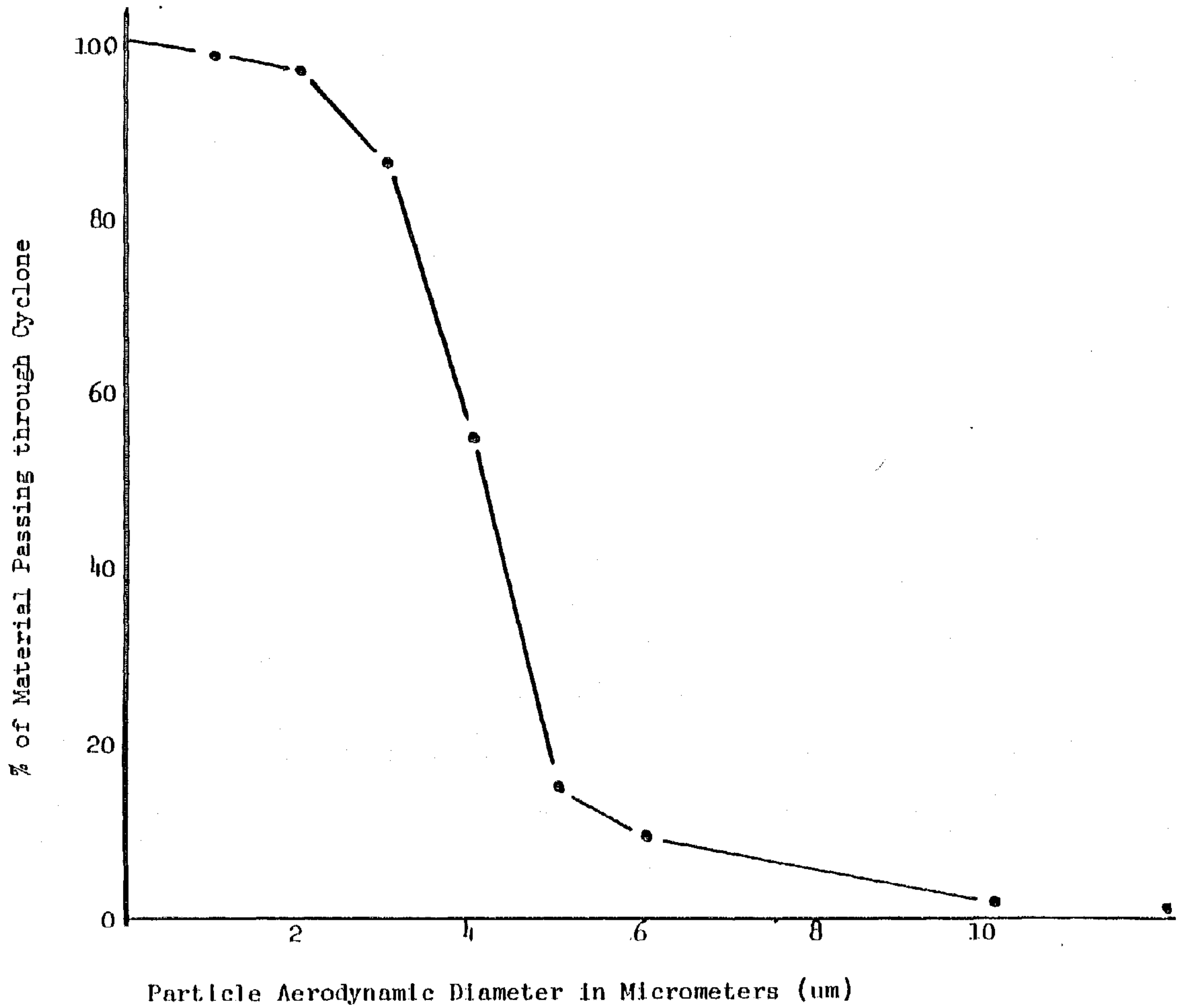
The Lone Star Cement plant in Nazareth, Pennsylvania was surveyed on Thursday, March 11 and Friday, March 12, 1982, by Greg Piacitelli and Wayne Sanderson. The plant is located near downtown Nazareth. The plant was built adjacent to a limestone quarry which serves as a calcium and aluminum source for cement production. We did not survey the quarry workers at this plant, however. Other raw materials such as iron ore and sand are trucked in from other companies. The raw materials are blended and milled in rotating ball mills and then stored until needed for clinker production. Clinkers are produced in four kilns by the dry process method. Two of the kilns were built in 1936 and two were built in 1957. All four kilns are fueled by pulverized coal. Only the two newer kilns were in operation during our survey. Gypsum is added to the clinker and it is milled in rotating ball mills to increase fineness; this material is Portland cement. Lone Star manufactures seven types of cement at this facility, and they are bagged or loaded as bulk in trucks or railcar.

Methods and Results

Personal Respirable and Total Dust Samples

It was not feasible nor statistically necessary to monitor all individuals at the plant. Using a random numbers table, a subset of workers was chosen to participate in the study. These selected workers were requested to wear a respirable or total dust sampler. To collect respirable dust, air was pulled through a 10 mm nylon cyclone and a polyvinyl chloride filter (PVC) at a flow rate of 1.7 liters per minute (lpm) by a personal sampling pump. At this flow rate, the cyclone separates the collected airborne dust into two fractions. Those particles considered respirable pass through the cyclone and are collected on the filter; larger particles or those considered to be non-respirable drop to the bottom of the cyclone and are discarded. The collection efficiency curve for this cyclone is presented in Figure 1. As defined by this curve, particles greater than 10 micrometers in aerodynamic diameter theoretically would not pass through the cyclone and be deposited on the filter. Whereas, almost all the particles smaller than 1.5 micrometers in aerodynamic diameter would be collected on the filter. (1) The basic sampling apparatus for respirable dust, minus the size selector, is used to collect total airborne dust. Air is pulled through a PVC filter mounted in a polystyrene filter holder at a flow rate of 1.7 lpm. Those particles 20 um and below are collected fairly efficiently on the filter media. This of course depends also on the direction, speed, density, and nearness of the particles to the filter. The filters were weighed on a precision balance to the nearest 0.01 milligram (mg), before and after sampling. The weight gain

Figure 1 COLLECTION EFFICIENCY OF THE PERSONAL RESPIRABLE DUST CYCLONE



of the filters, the sampling flow rates, and the sampling times were used to calculate airborne dust levels.

Respirable dust levels are reported in Table 2 as milligram per cubic meter (DUSTMGM3). The results from the respirable dust sampling are also summarized in Table 3, with summary statistics computed for each exposure category. The "MEAN" value is an arithmetic average of all values obtained in each area; the "STD" values are the standard deviations, which is a measure of the variability of the data. "GM" and "GSD" are the geometric means and geometric standard deviations of the same data respectively. Geometric values sometimes give a better estimate of expected values than do normal arithmetic averages because the effect of an occasional high value is diminished in calculating geometric means. The NLOD values are the number of samples which were less than the limit of detection. "MAX" and "MIN" values are maximum and minimum observed values for samples that had detectable amounts of materials. Arithmetic mean respirable dust levels are also charted in Figures 2 and 3 by process area and job category respectively. These are presented to provide easy recognition of the highest exposure areas and job categories.

After weighing, the respirable filters were subjected to analysis by x-ray diffraction to determine their content of quartz and cristobalite. (2) Crystalline silica is reported in Table 4 as microgram per cubic meter (QUARTZ) and percent quartz (PCT_SIO2). A value of "N" indicates that the measured quantity was below the analytical limit of detection. Limits of detection for each method are given in Table 1. Samples which had detectable quartz concentrations are also shown on Table 5 with their calculated MSHA-PEL. This will be discussed in detail in the Discussion Section.

Total dust levels are presented in Table 6. These results are summarized in Table 7. As with the respirable dust levels, arithmetic mean total dust levels are charted in Figures 4 and 5 by process area and job category respectively.

After weighing, the total dust filters were ashed in acid and analyzed by atomic absorption (3) to detect the amount of aluminum (AL), chromium (CR), cobalt (CO), magnesium (MG), manganese (MN), and nickel (NI) present. The trace metal concentrations are reported in Table 8 as micrograms per cubic meter of air (___ UGM3). Once again, a value of "N" indicates that the measured quantity was below the limit of detection. The limits of detection for each element are listed in Table 1. Trace metal analyses are summarized in Table 9. The MEAN is the arithmetic mean of all the samples with detectable levels of the particular elements. STD DEV is the standard deviation of these samples and is an expression of the variability of the elemental concentrations. No chromium, cobalt, or nickel was detected on any of the personal total samples.

Bulk Material Samples

Samples of raw material dust, clinker, finished product, and mixtures of dust were collected for analysis. These samples were generally collected from dust settled on ledges or objects several feet above the floor. For this reason, it is suspected that these particles were at one time suspended in air before coming to rest. These bulk material samples cannot, however, be considered airborne samples. This material was analyzed for content of quartz and cristobalite by x-ray diffraction; aluminum, chromium, cobalt, magnesium, manganese, and nickel content by atomic absorption; and asbestos content by polarized light and dispersion staining microscopy.

The results of these analyses are presented in Table 10. The "AREA" column lists from what exposure category the samples were taken, or whether the material was felt to be predominantly raw material, clinker, finished Portland cement, or a mixture of two or more types of dust. The results of analysis are presented as percent by weight of material. For example, if 1% of the raw material is quartz, there is 0.01 gram of quartz in each gram of raw material. The value "N" indicates that the measured quantity was below the analytical limit of detection.

Nitrogen Dioxide Samples

Nitrogen dioxide sampling was done using passive dosimeters for both area and personal sampling. Full-shift time-weighted average exposures were determined. Dosimeters were constructed by cutting lengths of acrylic tubing to give a length-to-area ratio of 10 to 1. One end of the tube was fitted with a removable cap-plug and the other end was sealed with a cap containing the collection grids. These grids were coated with triethanolamine which quantitatively absorbs NO_2. During exposure, the cap-plug was removed and the contaminant gas diffused to the collection grid according to Fick's Law of Diffusion. After collection a sulfanilamide-phosphoric acid-NEDA solution was added to the dosimeter, where a red color complex with NO_2 was formed. The solution was transferred to a spectrophotometer and the absorbtivity is measured at 540 nm. This was compared against a standard curve to give nanomoles NO_2, from which the concentration was calculated as: (14,15)

$$\text{conc, ppm} = \frac{\text{nanomoles } NO_2}{2.3 \times \text{Hours of Exposure}}$$

These samples were collected for periods between 6 and 8 hours. The measurements reflect the average concentration over this period. The results of the analysis are reported in Table 11. Nitrogen dioxide is produced from the combustion of nitrogen-containing organic compounds such as coal and diesel fuel.

<u>General Comments and Schedule</u>

Control filters were collected on site during the survey. These filters received treatment identical to dust laden filters, except no air was drawn through the control filters. During each shift, each personal and area sampler was periodically checked for proper operation. If the sampler was not operating properly, sampler adjustments and appropriate notations were made and, if necessary, the results of such samples were voided.

The environmental investigations team began sampling Thursday, March 11, 1982. The sampling schedule was as follows:

Thursday, March 11 - 2nd shift

Friday, March 12 - 1st shift

This schedule was used in order to adequately measure environmental concentration differences due to day-to-day and shift-to-shift variations.

Plant areas and the work force were separated into four exposure categories based on the type of airborne dust each was subjected to. The categories were:

raw - exposure to raw materials dust

clinker - exposure to clinker dust

finish - exposure to finished Portland cement dust

mix - exposure to a mixture of two or more types of dust

Although these categories are somewhat artificial, they are very important to the design of the study. Generally, the dust particles within a category area are chemically and physically similar; however, between categories the dusts are significantly different. The mix category serves to "catch" those jobs such as laborers and repairmen who work throughout the plant or are exposed to more than one type of dust.

Discussions and Conclusions

This study is designed to determine if the normal function of respiratory tissue is impaired because of exposure to gases or particulates found in Portland cement plants. Samples of airborne particulate were collected in conjunction with a medical examination that included x-rays, spirometry tests, and symptoms questionnaires. Respiratory problems associated with exposure to airborne particulate are influencd by four factors: (4)

1. The type of dust involved
2. The length of exposure time
3. The concentration of airborne dusts in the breathing zone
4. The size of the dust particles

The intent of the environmental portion of the study is to determine the types and concentration of airborne materials to which cement workers are exposed.

This survey was not conducted for regulation compliance purposes. This data presented here is to be used for correlation with employee medical data for occupational health research. Air quality and physical agents in Portland cement plants are currently regulated by Title 30, section 56.5 of the Mineral Resources Code of Federal Regulations. The 1973 Threshold Limit Values, (TLV's), adopted by the American Conference of Governmental Industrial Hygienists, (ACGIH), are cited as the standards which airborne contaminants are not allowed to exceed. In this report these standards serve only as reference levels in order for plant personnel to compare the environmental conditions of their facility.

Personal Respirable and Total Dust Samples

Portland Cement is presently considered to be a "nuisance" dust. "Nuisance" particulates, by definition, have "little adverse effect on lungs and do not produce significant organic disease or toxic effect when exposures are kept under reasonable control. Generally, the lung-tissue reaction caused by inhalation of nuisance dusts has the following characteristics:

1. The architecture of the air spaces remains intact.
2. Collagen (scar tissue) is not formed to a significant extent.
3. The tissue reaction is potentially reversible." (5)

If airborne particulates contain greater than 1% crystalline silica, then they are no longer considered nuisance particulates; they are mineral dusts. The MSHA standard for nuisance dusts is 10 milligrams per cubic meter of total suspended dust. The MSHA standard for mineral dusts employs the formula:

$$PEL = \frac{10 \text{ mg/m}^3}{\% \text{ respirable quartz} + 2}$$

where the "% respirable quartz" is the percent by weight of quartz in each sample, and "PEL" is the permissible exposure level. Therefore, each respirable dust sample for mineral dust has an exposure limit based on its content of quartz.

The emphasis of this survey was on respirable dust sampling. It is difficult to compare respirable dust measurements to the currently employed MSHA nuisance dust standard which is based on total dust levels. We recommend comparison of the respirable dust levels to the 5 mg/m^3 TLV for respirable nuisance dust recommended by the ACGIH.

Examining the personal respirable samples collected from the various jobs, Table 2, only one sample exceeded 5 mg/m^3. This sample was collected from a mill helper who worked his shift on the second floor of the mill room, cleaning up around all eight mills, and filling hoppers with grinding aids. For all workers the geometric mean respirable dust level was 0.71 mg/m^3.

Two personal total dust samples, Table 6, exceeded 10 mg/m^3. These samples were worn by a packer and a maintenance man working in the packhouse. The geometric mean total dust level for all workers was 7.72 mg/m^3.

Because of the differences in worker duties and activities, some jobs consistently encounter higher or lower dust levels than other jobs. However, within a given job category, variability is often slight. Figures 3 and 5 chart the means of the respirable and total dust measurements respectively, for each job. Repairmen, packhouse workers, and mill workers had the highest dust exposures. Activities of these workers either generate considerable amounts of dust, or take them into areas of heavy dust exposure. Most of the other jobs involve activities that do not generate much dust, or the workers were isolated from the dust source by enclosures.

Crystalline Silica

Quartz was detected in bulk samples of crushed stone (8-9%), kiln feed (10%), clinker (8-10%), and masonry cement (6%). Quartz is a common constiutent of limestone, shale, clay, and sand, but is rarely found in clinker or finished cement. As silicon dioxide passes through the high kiln temperatures, it is transformed from free crystalline forms into silicates. It is unusual to find quartz in clinker, particularly in concentrations of 8 and 10%. The clinker bulk samples on Table 10 were collected at the clinker cooler, fire end of kiln 2, and the clinker storage silo, respectively. Quartz-containing material may be added in the grinding phase of masonry cement production. No quartz was detected in any other finished cement sample. These samples indicate that workers associated with raw materials, clinker, and masonry cement are potentially exposed to quartz.

All personal respirable dust samples were analyzed for content of the crystalline mineral types, quartz and cristobalite. Eight personal respirable dust samples contained detectable levels of quartz. The silo operator worked around the homogenizing silos and the kiln precipitator area. The crane operators transferred raw material to appropriate bins. They transferred primarily stone, but also some sand and iron ore. The kiln feed operator worked in the kiln feed silos. These four workers were mainly exposed to raw material dust during their shift. The laborer spent his shift cleaning up in the raw and finish mill areas. The repairman had been all over the plant performing routine maintenance checks. The mill helper was checking raw and clinker silo levels and cleaning up around raw mill elevators. The mill operator was all over the mill building during his shift. These four workers were exposed to two or more types of dust, including raw material dust.

There may be some variation in quartz concentration depending on the composition of the raw materials that employees are working with. Also, the mixing and grinding of various materials containing quartz will result in a range of concentrations. Therefore, the free silica concentrations may vary with area and time. The calculated percent of quartz on the respirable filters (Table 4) have a range of 2.9 - 20.0%.

Table 5 lists the jobs with detectable levels of quartz, the percent quartz by weight in each sample, and the concentration of that dust allowed by MSHA. Three of the eight samples exceed the permissible exposure limit. One of the eight samples with detectable levels of quartz contained concentrations greater than 100 ug/m^3. Exposures below this level have been suggested in past research as safe levels of exposure. (6,7,8)

Trace Metals

The personal total dust samples were analyzed for the six trace metals: aluminum, chromium, cobalt, magnesium, manganese, and nickel. From the personal samples, none of the metals were found in concentrations greater than the MSHA permissible exposure levels or the ACGIH recommended TLV's. Aluminum and magnesium are commonly found in the dust particles. Manganese is occasionally found. None of the samples contained detectable amounts of chromium, cobalt, or nickel. Aluminum is present in the greatest concentration, followed by magnesium. Raw material, clinker, and finished cement dust all contain aluminum and magnesium. Variation in the presence of metals and their concentration may be caused by differences in milling or processing. We chose to measure these six metals because nickel and chromium are suspected carcinogens, and aluminum, magnesium, manganese, and cobalt are suspected pneumoconiosis or bronchitis producing agents. There are no past studies to indicate that these elements will cause any disease in the form or concentrations found in a cement plant. This study will look for correlations between respiratory health problems and exposures to these elements.

Nitrogen Dioxide

Nitrogen dioxide is a reddish-brown gas which is a common contaminant in the exhaust of internal combustion engines. It is an irritant to the mucous membranes and its inhalation may cause coughing, sometimes severe, which may be accompanied by mild or transient headache. (16)

Based on animal studies, ACGIH recommends a ceiling limit (the concentrations, not to be exceeded even instantaneously) of 5 ppm. (5) This level was considered sufficiently low to insure against immediate injury or adverse physiologic effects from prolonged daily exposures. The present federal standard (MSHA and OSHA) for nitrogen dioxide is 5 ppm as an 8-hour time-weighted average (TWA). (18) This was based upon the ACGIH TLV except that the ceiling designation was omitted. (16) A number of human experiments and animal studies suggest that humans with normal respiratory function may be affected by exposure at or below this level and that the conditions of workers with disease such as bronchitis may be aggravated by such exposures. (19,20,21,22) NIOSH recommends a ceiling of 1 ppm to protect workers with pre-existing chronic bronchitis. ACGIH maintains a STEL of 5 ppm and a TWA of 3 ppm.

All of the 24 samples taken at Lone Star Cement were below the recommended standard.

Background Samples

Samples placed upwind of the cement plant exhibit very low levels of dust. No trace metals, asbestos, or crystalline silica were detected on these background samples. Since Lone Star Cement is situated among other industries, the background respirable and total dust levels may fluctuate with changes in atmospheric conditions. These dust levels represent the dust exposures people would experience by just being in the community. One approach to data analysis might be to subtract these dust levels from measured plant concentrations. This would give values which represent the additional dust burden attributed to the operation of this plant. Tables 2 and 3 list the background respirable dust levels and their descriptive statistics.

Conclusion

The respirable and total dust levels for most jobs at the Lone Star Cement Plant in Nazareth, Pennsylvania are below recommended exposure levels. One sample from a mill helper exceeded the ACGIH recommended level for respirable nuisance particulate. Two total dust samples from a maintenance worker and packer exceeded the 10 mg/m^3 MSHA PEL for nuisance dust. Eight respirable dust samples contained detectable levels of quartz. Three of these samples exceeded the MSHA-PEL for respirable quartz. Of the dust contaminants measured, only quartz is considered to be present in excessive concentrations. Exposure to quartz occurs in association with the raw materials, clinker, and masonry cement. Protective measures should be taken.

Recommendations

Because quartz was detected in bulk samples and respirable dust samples from several jobs, we recommend workers to be occasionally monitored, to assure exposures remain below recommended quartz concentrations. When concentrations are found to be excessive we recommend the following control practices.

Engineering controls are the most effective means of reducing worker exposure to airborne dust. These controls should be maintained in efficient working order. Ventilation design to remove the dust from the air once it is generated and separation from the dust by enclosing either the worker or the dust are effective means of control. The priority for implementing dust control measures should begin with areas of highest exposure and those areas where exposure to silica occurs..

The highest exposures were from workers in the mill and packing areas. During clean-up operations in the mills with shovels and brooms, settled dust is resuspended. Substitution with a vacuum system would eliminate this problem. Because packers are stationary, ventilation fans may be placed above or behind packers to blow fugitive dust away from their breathing zone. Helmets attached to ventilation hoses, which supply air to cool the workers and prevent dust from entering the helmet, are an effective control measure for stationary workers which cannot be enclosed from dust sources.

Although engineering controls are the recommended course of action, personal protective equipment (respirators and goggles) may be used by workers whenever engineering controls are not available or during maintenance, repair, and clean-up operations. The disposable paper or cloth respirators do not form an occlusive seal between the respirator and the face. Dust particles would be able to pass through leaks between the respirator and the face. Whenever workers are potentially exposed to excessive quartz concentrations, quarter or half mask dust-fume-mist respirators should be used. The disposable respirators will, however, provide some protection to workers exposed to nuisance particulates. If workers complain of eye irritation, full-face piece respirators may be used instead of half or quarter mask respirators to alleviate the problems. It is suggested that workers be involved in the selection of a comfortable NIOSH/MSHA approved dust-fume-mist respirator and be fit-tested to ensure that they are adequately protected.

The corrective actions recommended should be viewed as scientific guidance. There is no legal requirement that you implement any of these recommendations, and no assurance that these actions, if implemented, would be sufficient to prevent future citations for non-compliance. Nevertheless, it is anticipated that implementation of the recommendations listed in this report will reduce airborne dust levels at this facility, and improve the environmental conditions of the workplace.

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Table 1

Environmental Investigations Branch

Industrial Hygiene Survey of Cement Workers
Lone Star Cement, Nazareth, Pennsylvania

Number of Samples With Detectable Levels of Contaminants

Contaminant	# Samples Collected	# Samples with Detectable Conc.	Limit of Detection
Respirable dust	32	32	0.01 mg
Total dust	5	5	0.01 mg
Quartz	32	8	0.03 mg
Cristobalite	32	0	0.03 mg
Aluminum	5	5	0.20 mg
Chromium	5	0	0.004 mg
Cobalt	5	0	0.005 mg
Magnesium	5	5	0.002 mg
Manganese	5	1	0.002 mg
Nickel	5	0	0.004 mg
Nitrogen dioxide	24	24	0.02 ppm

Table 2

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LONE STAR CEMENT NAZARETH, PENNSYLVANIA
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
GROUPED BY EXPOSURE AREA

AREA=BACKGROUND

JOB	DATE	SHIFT	DUSTMGM3
BACKGROUND	12MAR82	1	0.01

AREA=RAW

JOB	DATE	SHIFT	DUSTMGM3
SILO OPERATOR	11MAR82	2	0.93
CRANE OPERATOR (RAW)	11MAR82	2	0.49
KILN FEED OPERATOR	11MAR82	2	1.10
CONVEYOR OPERATOR	11MAR82	2	0.39
CRANE OPERATOR (RAW)	12MAR82	1	0.72
KILN FEED OPERATOR	12MAR82	1	0.82

AREA=CLINKER

JOB	DATE	SHIFT	DUSTMGM3
CRANE OPER (CLINKER)	11MAR82	2	0.26
KILN BURNER	11MAR82	2	0.17
TRUCK DRIVER (CLINKER)	12MAR82	1	0.43
KILN BURNER	12MAR82	1	0.39
COOLER OPERATOR	12MAR82	1	1.29
REBRICKER	12MAR82	1	2.53

AREA=FINISH

JOB	DATE	SHIFT	DUSTMGM3
TUNNELMAN (FINISH)	11MAR82	2	0.80
TUNNELMAN (FINISH)	11MAR82	2	1.26
FORKLIFT OPERATOR (FINISH)	12MAR82	1	0.19
PACKER	12MAR82	1	0.01
UTILIYMAN (FINISH)	12MAR82	1	0.23
PACKER	12MAR82	1	0.87

AREA=MIX

JOB	DATE	SHIFT	DUSTMGM3
LABORER	11MAR82	2	0.64
MILL HELPER (MIX)	11MAR82	2	4.05
MILL HELPER (MIX)	11MAR82	2	10.08
MILL OPERATOR	11MAR82	2	1.41
OILER (KILN)	11MAR82	2	0.33
REPAIRMAN	11MAR82	2	1.08
ELECTRICIAN	11MAR82	2	1.30

Table 2

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LONE STAR CEMENT   NAZARETH, PENNSYLVANIA
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
GROUPED BY EXPOSURE AREA

AREA=MIX

JOB	DATE	SHIFT	DUSTMGM3
MILL HELPER (MIX)	11MAR82	2	1.69
YARD WORKERS	12MAR82	1	0.87
OILER (KILN)	12MAR82	1	0.78
WELDER	12MAR82	1	2.40
REPAIRMAN	12MAR82	1	1.38
REPAIRMAN	12MAR82	1	0.54
ELECTRICIAN	12MAR82	1	0.42

Table 3

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LONE STAR CEMENT NAZARETH, PENNSYLVANIA
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3

AREA	SAMPLES	MEAN	STD	GM	GSD	NLOD	MIN	MAX
BACKGROUND	1	0.01	.	0.01	.	0	0.01	0.01
RAW	6	0.74	0.27	0.70	1.48	0	0.39	1.10
CLINKER	6	0.85	0.92	0.54	2.75	0	0.17	2.53
FINISH	6	0.56	0.49	0.27	5.96	0	0.01	1.26
MIX	14	1.93	2.54	1.21	2.49	0	0.33	10.08
PLANTWIDE	32	1.24	1.81	0.71	3.23	0	0.01	10.08

Figure 2

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LONE STAR CEMENT   NAZARETH, PENNSYLVANIA
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
ARITHMETIC MEAN VALUES BY AREA

BAR CHART OF MEANS

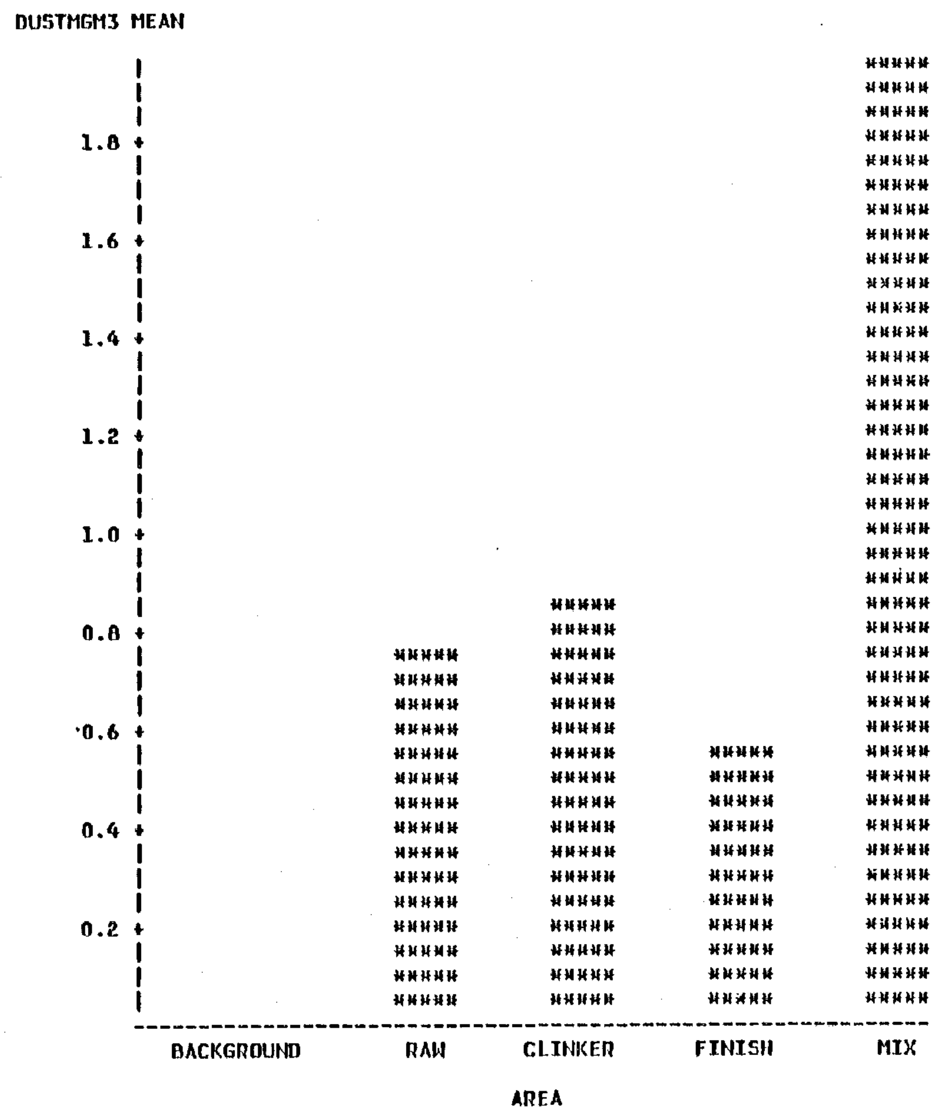

Figure 3

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LONE STAR CEMENT   NAZARETH, PENNSYLVANIA
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
ARITHMETIC MEAN VALUES BY JOB CATEGORY

BAR CHART OF MEANS

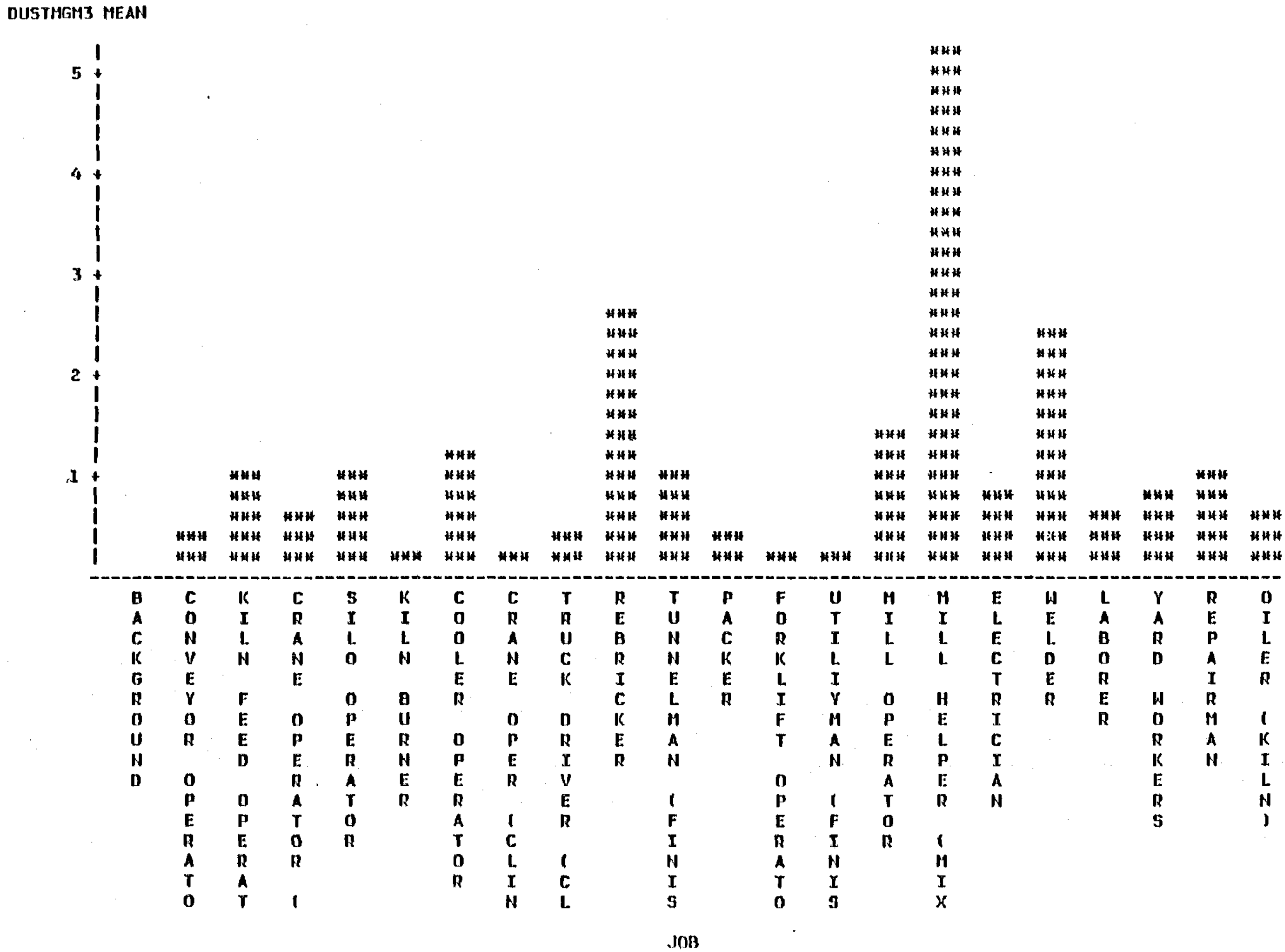

Table 4

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LONE STAR CEMENT   NAZARETH, PENNSYLVANIA
QUARTZ CONCENTRATION OF PERSONAL RESPIRABLE DUST SAMPLES
QUARTZ CONCENTRATION IN MICROGRAMS PER CUBIC METER (UG/M3)

JOB	DATE	SHIFT	PCT_SIO2	QUARTZ	AREA
SILO OPERATOR	11MAR82	2	8.3	77.16	RAW
CRANE OPERATOR (RAW)	11MAR82	2	20.0	98.30	RAW
KILN FEED OPERATOR	11MAR82	2	5.6	61.06	RAW
CONVEYOR OPERATOR	11MAR82	2	N	N	RAW
KILN FEED OPERATOR	12MAR82	1	N	N	RAW
CRANE OPERATOR (RAW)	12MAR82	1	7.3	52.65	RAW
KILN BURNER	11MAR82	2	N	N	CLINKER
CRANE OPER (CLINKER)	11MAR82	2	N	N	CLINKER
COOLER OPERATOR	12MAR82	1	N	N	CLINKER
TRUCK DRIVER (CLINKER)	12MAR82	1	N	N	CLINKER
REBRICKER	12MAR82	1	N	N	CLINKER
KILN BURNER	12MAR82	1	N	N	CLINKER
TUNNELMAN (FINISH)	11MAR82	2	N	N	FINISH
TUNNELMAN (FINISH)	11MAR82	2	N	N	FINISH
FORKLIFT OPERATOR (FINISH)	12MAR82	1	N	N	FINISH
UTILIYMAN (FINISH)	12MAR82	1	N	N	FINISH
PACKER	12MAR82	1	N	N	FINISH
PACKER	12MAR82	1	N	N	FINISH
MILL HELPER (MIX)	11MAR82	2	N	N	MIX
LABORER	11MAR82	2	9.4	59.74	MIX
REPAIRMAN	11MAR82	2	7.8	84.58	MIX
ELECTRICIAN	11MAR82	2	N	N	MIX
MILL HELPER (MIX)	11MAR82	2	N	N	MIX
MILL HELPER (MIX)	11MAR82	2	2.9	116.97	MIX
OILER (KILN)	11MAR82	2	N	N	MIX
MILL OPERATOR	11MAR82	2	4.1	57.87	MIX
WELDER	12MAR82	1	N	N	MIX
YARD WORKERS	12MAR82	1	N	N	MIX
ELECTRICIAN	12MAR82	1	N	N	MIX
REPAIRMAN	12MAR82	1	N	N	MIX
OILER (KILN)	12MAR82	1	N	N	MIX
REPAIRMAN	12MAR82	1	N	N	MIX

Table 5

Environmental Investigations Branch

Industrial Hygiene Survey of Cement Workers
Lone Star Cement, Nazareth, Pennsylvania

Detectable Quartz Compared to MSHA Permissible Exposure Levels

Job	Levels of Dust Conc. Mg/m^3	Quartz Conc. % Quartz	ug/m^3	MSHA PEL mg/m^3
Silo operator	0.93	8.3	77.16	0.97
Crane operator	0.49*	20.0	98.3	0.45
Kiln feed op.	1.10	5.6	61.06	1.32
Crane operator	0.72	7.3	52.65	1.08
Laborer	0.64	9.4	59.74	0.88
Repairman	1.08*	7.8	84.58	1.02
Mill helper	4.05*	2.9	116.97	2.04
Mill operator	1.41	4.1	57.87	1.64

*Indicates measured concentration exceeds the MSHA Permissible Exposure Limit.

Table 6

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LONE STAR CEMENT   NAZARETH, PENNSYLVANIA
PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3
GROUPED BY EXPOSURE AREA

AREA=RAW

JOB	DATE	SHIFT	DUSTMGM3
SILO OPERATOR	12MAR82	1	4.21

AREA=FINISH

JOB	DATE	SHIFT	DUSTMGM3
MAINTENANCE (FINISH)	12MAR82	1	24.19
PACKER	12MAR82	1	14.47

AREA=MIX

JOB	DATE	SHIFT	DUSTMGM3
YARD WORKERS	12MAR82	1	6.72
DUST COLLECTOR	12MAR82	1	2.77

Table 7

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LONE STAR CEMENT   NAZARETH, PENNSYLVANIA
PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3

AREA	SAMPLES	MEAN	STD	GM	GSD	NLOD	MIN	MAX
RAW	1	4.21	.	4.21	.	0	4.21	4.21
FINISH	2	19.33	6.87	18.71	1.44	0	14.47	24.19
MIX	2	4.74	2.80	4.31	1.87	0	2.77	6.72
PLANTWIDE	5	10.47	8.90	7.72	2.42	0	2.77	24.19

Figure 4

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LONE STAR CEMENT NAZARETH, PENNSYLVANIA
PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3
ARITHMETIC MEAN VALUES BY AREA

BAR CHART OF MEANS

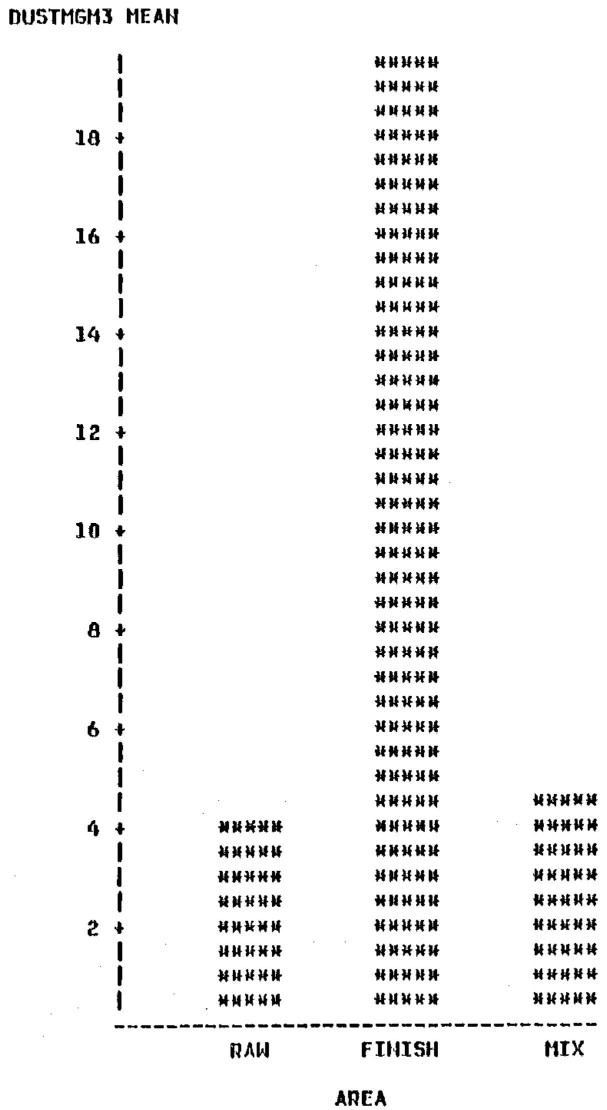

Figure 5

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LONE STAR CEMENT   NAZARETH, PENNSYLVANIA
PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3
ARITHMETIC MEAN VALUES BY JOB CATEGORY

BAR CHART OF DUSTMGM3

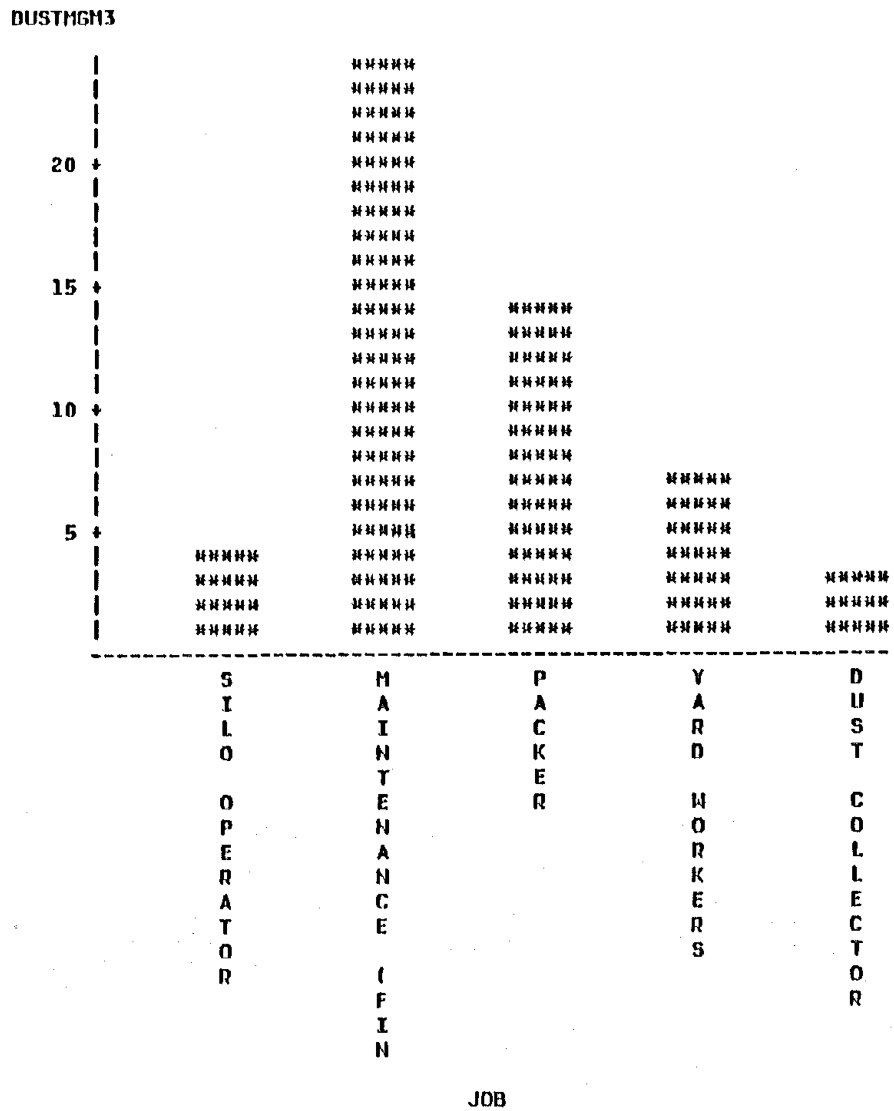

Table 8

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LONE STAR CEMENT NAZARETH, PENNSYLVANIA
TRACE METAL CONCENTRATIONS OF PERSONAL TOTAL DUST SAMPLES
CONCENTRATIONS IN MICROGRAMS PER CUBIC METER (UG/M3)

AREA	DATE	SHIFT	JOB	AL_UGM3	CR_UGM3	CO_UGM3	MG_UGM3	MN_UGM3	NI_UGM3
RAW	12MAR82	1	SILO OPERATOR	68	N	N	38	N	N
FINISH	12MAR82	1	PACKER	247	N	N	152	N	N
FINISH	12MAR82	1	MAINTENANCE (FINISH)	398	N	N	271	9	N
MIX	12MAR82	1	DUST COLLECTOR	55	N	N	32	N	N
MIX	12MAR82	1	YARD WORKERS	104	N	N	39	N	N

Table 10

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LONE STAR CEMENT   NAZARETH, PENNSYLVANIA
ANALYSIS OF BULK MATERIAL PRESENTED AS PERCENT BY WEIGHT

AREA	JOB	QUARTZ	CRISTB	AL	CR	CO	MG	MN	NI	ASBEST
RAW	RAW MATERIAL	9.0	N	0.79	N	N	1.3	0.028	N	0.0
RAW	RAW MATERIAL	8.0	N	0.82	N	N	1.1	0.029	N	0.0
RAW	RAW MATERIAL	8.0	N	1.10	N	N	1.2	0.029	N	0.0
RAW	RAW MATERIAL	10.0	N	1.80	N	N	1.2	0.035	N	0.0
CLINKER	CLINKER	8.0	N	1.10	N	N	1.3	0.035	N	0.0
CLINKER	CLINKER	N	N	2.30	N	N	1.8	0.036	N	0.0
CLINKER	CLINKER	10.0	N	0.64	N	N	1.1	0.037	N	0.0
FINISH	FINISH	N	N	2.70	N	N	1.9	0.480	N	0.0
FINISH	FINISH	N	N	2.90	N	N	1.7	0.040	N	0.0
FINISH	FINISH	N	N	2.40	N	N	1.6	0.069	N	0.0
FINISH	FINISH	N	N	2.90	N	N	1.7	0.040	N	0.0
FINISH	FINISH	N	N	2.90	N	N	1.8	0.041	N	0.0
FINISH	FINISH	N	N	3.00	N	N	1.8	0.042	N	0.0
FINISH	FINISH	6.0	N	2.10	N	N	1.5	0.035	N	0.0
FINISH	FINISH	6.0	N	2.40	N	N	1.5	0.036	N	0.0

Table 11

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LONE STAR CEMENT NAZARETH, PENNSYLVANIA
NO2 CONCENTRATIONS IN PPM

JOB	DATE	SHIFT	AREA	CONC
BACKGROUND	12MAR82	1	BACKGROUND	0.02
KILN FEED OPERATOR	11MAR82	2	RAW	0.04
CRANE OPERATOR (RAW)	12MAR82	1	RAW	0.02
KILN FEED OPERATOR	12MAR82	1	RAW	0.02
KILN BURNER	11MAR82	2	CLINKER	0.02
TRUCK DRIVER (CLINKER)	12MAR82	1	CLINKER	0.03
KILN BURNER	12MAR82	1	CLINKER	0.02
COOLER OPERATOR	12MAR82	1	CLINKER	0.03
REBRICKER	12MAR82	1	CLINKER	0.03
TUNNELMAN (FINISH)	11MAR82	2	FINISH	0.06
FORKLIFT OPERATOR (FINISH)	12MAR82	1	FINISH	0.04
PACKER	12MAR82	1	FINISH	0.19
UTILIYMAN (FINISH)	12MAR82	1	FINISH	0.06
PACKER	12MAR82	1	FINISH	0.07
MILL HELPER (MIX)	11MAR82	2	MIX	0.07
MILL HELPER (MIX)	11MAR82	2	MIX	0.04
MILL OPERATOR	11MAR82	2	MIX	0.06
OILER (KILN)	11MAR82	2	MIX	0.07
ELECTRICIAN	11MAR82	2	MIX	0.01
MILL HELPER (MIX)	11MAR82	2	MIX	0.04
YARD WORKERS	12MAR82	1	MIX	0.03
OILER (KILN)	12MAR82	1	MIX	0.04
WELDER	12MAR82	1	MIX	0.01
REPAIRMAN	12MAR82	1	MIX	0.10
REPAIRMAN	12MAR82	1	MIX	0.03

APPENDIX

Physiological Response

The main function of the lungs is to keep the oxygen and carbon dioxide content of the arterial blood within a certain narrow range. In order to accomplish this, the lungs must bring the blood in contact with the air. The lungs are ventilated by a bellows action, when the chest cavity is expanded by the contraction of the diaphragm. This creates a negative pressure in the lungs causing air to rush in.

When a person breathes, air is drawn through the nose into the nasopharynx and trachea. From there it reaches the alveoli or area of gas exchange through a system of ducts: the bronchi, respiratory bronchioles, and the terminal bronchioles. It is in the alveoli where the blood is oxygenated and carbon dioxide diffuses into the lungs to be excreted. Deposition of airborne particles occurs as a consequence of several different physical processes. Of primary concern are sedimentation, inertial impaction, and diffusion. Sedimentation is simply the settling out of particles onto respiratory tissue under the influence of gravity. Inertial impaction occurs when the momentum of particles being carried along in an air current carries them along their original path when the air current changes direction. The particles may then be deposited on the surface of respiratory tissue. Besides sedimentation and impaction, very small particles are affected by diffusion. Since movement of small particles in air is completely random, those that are in close proximity to the alveolar wall are likely to collide with it and hence be deposited. (15)

In order to remove particles from the respiratory system, two separate mechanisms are present. Those particles deposited in the upper airways are removed by the mucociliary escalator. In the upper airways there is a series of tiny hairs or cilia which are continually sweeping mucous and particles upward toward the throat. The mucous provides a sticky layer to capture and hold the particulate, while the cilia remove it from the respiratory system. In the terminal bronchioles and the alveoli, deposited material is removed by phagocytes; or cells which actually consume the particles and digest them.

Problems arise, however, when the respiratory system is overcome. Whenever there is a high concentration of dust, the mucociliary escalator and the phagocytes may not be able to remove all of the particles. Also, the particles may possess unique properties which prevent the natural defenses of the lung from eliminating them.

It is the intent of this study to determine which materials may be toxic to the respiratory system, and what concentration and duration of exposure may produce physiological changes.