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Industrial Hygiene Survey of Lehigh Cement Co.

Mitchell, Indiana

Cement Workers Morbidity Study

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Executive Summary

The Lehigh Cement Plant in Mitchell, Indiana was surveyed by a NIOSH team of industrial hygienists, on November 18 through November 23, 1981. Samples were collected and analyzed for respirable and total dust, free crystalline silica, aluminum, cobalt, magnesium, manganese, nickel, other trace elements, asbestos, nitrogen dioxide, and oxides of sulfur.

The respirable and total dust levels for most jobs are below recommended exposure levels. One sample exceeded the ACGIH recommended level of 5.0 mg/m^3 for respirable nuisance particulate. Three personal total dust samples exceeded the MSHA standard of 10 mg/m^3 for nuisance dust.

Respirable samples from a dust collector and laborer exceeded the MSHA-PEL for respirable quartz. Of the dust contaminants measured, only quartz is considered to be present in excessive concentrations.

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. Lehigh Cement in Mitchell, Indiana was the fourteenth 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 Lehigh Cement plant in Mitchell, Indiana was surveyed on Wednesday, November 18 through Monday, November 23, 1981, by Rebecca West, Greg Kullman, and Wayne Sanderson. The Lehigh plant is located east of downtown Mitchell. The original plant was built in 1904 a mile from a limestone quarry which still serves as a source of raw material for cement production. Limestone is crushed at the quarry site and then transferred to the plant by conveyor belt. It is mixed with shale, iron ore, and sand, and milled in rotating ball mills. Clinker is produced from the raw mix in three kilns by the dry process production method. Two of the kilns were built in 1960. The third kiln which began operations in 1976 is a preheater/kiln system. All three kilns are fueled by pulverized coal. During our survey one of the older kilns was down for repairs. The clinkers are mixed with gypsum and milled in ball mills at the plant site. Four types of finished cement are manufactured here and are loaded as bulk in trucks or railcars. Approximately 170 workers are employed at Lehigh, including the quarry workers.

Methods and Results

Personal Respirable and Total Dust Samples

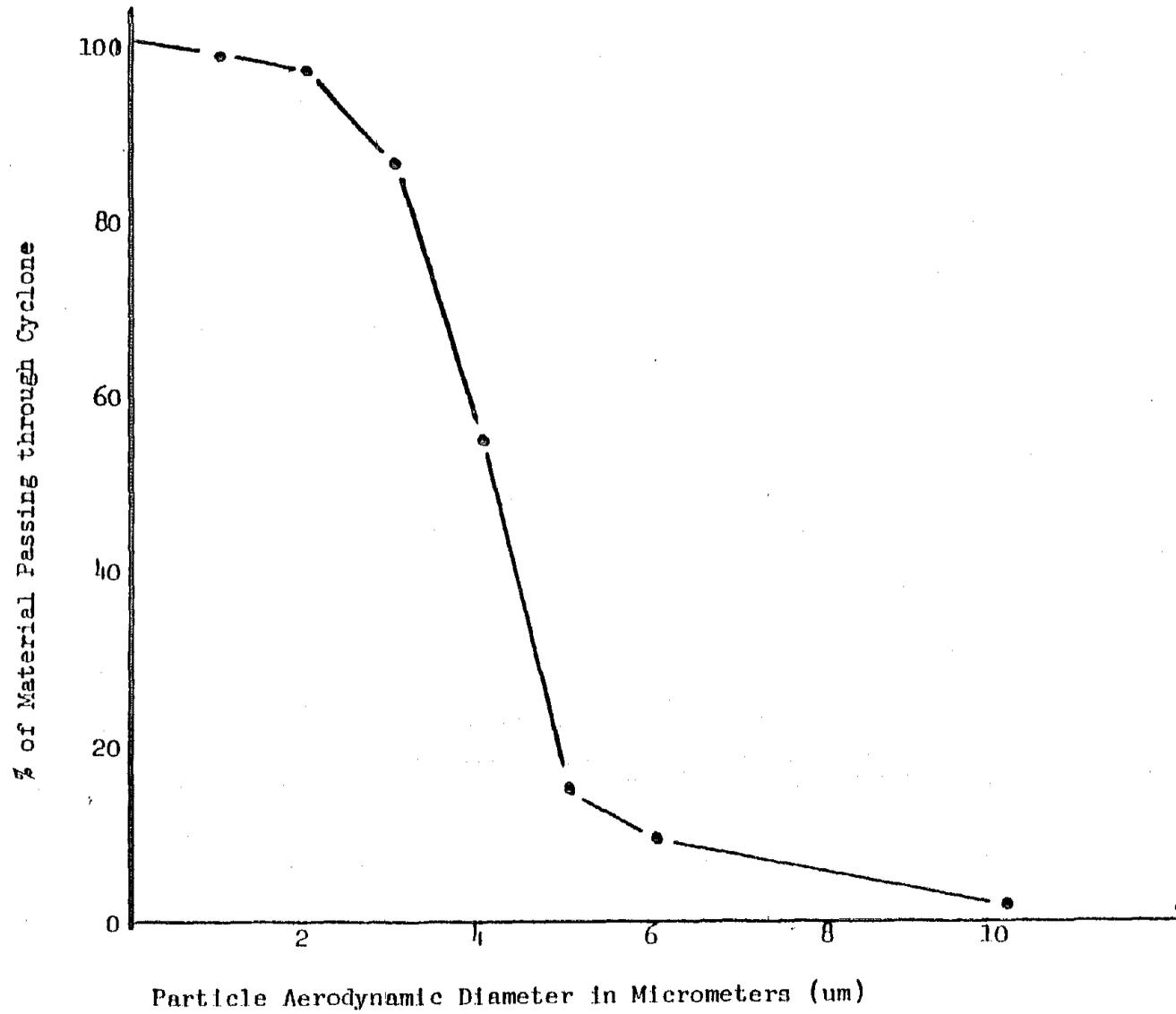
It was not feasible nor statistically necessary to monitor all individuals at the plant. Using a random numbers table, a subset of workers was chosen to participate in the study. These selected workers were requested to wear a

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 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 (DUSTMG/M3). The results from the respirable dust sampling are also summarized in Table 3, with summary statistics computed for each exposure category. The

Figure 1

COLLECTION EFFICIENCY OF THE PERSONAL RESPIRABLE DUST CYCLONE



"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 further 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.

Area Total Dust Samples

Airborne "total" dust samples were collected at fixed locations throughout the plant. These areas were selected based on how well they represented the work station of the employees. These filters were also analyzed for amount of aluminum, chromium, cobalt, magnesium, manganese, and nickel.

The trace metal concentrations are reported in Table 10 as micrograms per cubic meter of air (___ UGM3). The JOB column defines the area in which the

sample was collected. The six trace metal concentrations are then given in the next six columns. The results of the trace metal analysis of the area total samples are summarized in Table 11.

One area sample from each exposure category was analyzed for content of 28 metals. These samples were ashed using nitric and perchloric acids and the residues dissolved in dilute nitric acid. The resulting solutions were analyzed for trace metal content by inductively coupled plasma - atomic emission spectroscopy (ICP-AES). (4) The results of the analysis are reported in Table 12. For this analysis technique, the lower limit of detection is 1.0 ug/filter for all elements.

Airborne Fiber Samples

Samples for airborne fibers and asbestos were collected on cellulose ester filters. These samples are taken with the front of the filters completely open to the environment. Air is drawn through the filters at a flow rate of 1.7 ipm. These filters are optically analyzed using a phase contrast microscope. (5) If fibers were detected, they would have been analyzed by polarized light and dispersion staining, and transmission electron microscopy to determine whether they were asbestos fibers.

In this survey 13 samples were collected for fibers. These samples were collected in the raw material crushing and milling areas, storage areas, kiln areas, and along transfer belts. No fibers were detected on any of the filters.

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 13. 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.

Oxides of Sulfur Samples

Samples for sulfate and sulfite particulates and sulfur dioxide gas were collected by drawing a known volume of air through a filter train consisting of two cellulose ester filters in series. Particulate matter, including sulfates and sulfites, is collected on the first filter. Sulfur dioxide

passes through the first filter and is collected on the second filter which has been impregnated with potassium hydroxide. (6) The filters were extracted with deionized water and the extracts analyzed by ion-chromotography.

The results of the analysis are reported in Table 14. The JOB column lists where the sample was collected. The SO₄_UGM3 and SO₃_UGM3 columns give the sulfate and sulfite particulate concentrations in micrograms per cubic meter. The SO₂_PPM column gives the sulfur dioxide concentrations in parts per million. The analytical limits of detection for these compounds are listed in Table 1.

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 NO₂. 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 NO₂ 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 NO₂, from which the concentration was calculated as: (20, 21)

$$\text{Conc, ppm} = \frac{\text{nanomoles NO}_2}{2.3 \times (\text{Hours of Exposure})}$$

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 presented in Table 15. Nitrogen dioxide is produced from the combustion of organic compounds containing nitrogen such as coal and diesel fuel.

Direct Reading Indicator Tubes for Toxic Gases

Draeger direct reading indicator tubes were used to sample for sulfur dioxide (SO₂), carbon monoxide (CO), nitrogen dioxide (NO₂), oxides of nitrogen (NOX), ammonia (NH₃), and hydrochloric acid (HCl). Air is drawn through these tubes by a hand-held bellows pump. These tubes contain reactive indicator materials which change color when they are exposed to specific gases. The length of stain indicates the concentration of gas present in the environment. On this survey, NIOSH Certified Detector Tubes were used. They are certified to produce results within +25% of the true concentration at levels between one and five times the TLV, and within +35% of one-half of the TLV. For purposes of this study, this level of precision is adequate since a 25% variation around a given exposure level is not likely to produce significant differences in physiological response. The results of the detector tube samples are listed in Table 16.

General Comments and Schedule

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 Wednesday, November 18, 1981. The sampling schedule was as follows:

Wednesday, November 18 - 2nd shift
Thursday, November 19 - 1st shift
Friday, November 20 - 1st shift
Friday, November 20 - 3rd shift
Monday, November 23 - 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 influenced by four factors:(7)

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."⁽⁸⁾

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 worn by a dust collector who was primarily hauling waste precipitator dust from the collection bin to the dump. No personal samples from the raw, clinker, or

finished cement areas were greater than 5 mg/m^3 . For all workers the geometric mean dust level was 0.69 mg/m^3 .

Three personal total dust samples, Table 6, exceeded 10 mg/m^3 . These samples were collected from a mill helper, crane operator, and vacuum truck driver. The mill helper assisted the mill operator and spent most of his shift above the mills and in the blending bin building. The crane operator transfers clinker, limestone, shale, and sand in the craneway bins. Although he is in an enclosed cab, the crane is in a very dusty atmosphere. The vacuum truck driver cleans up areas of the plant by sucking up dust through large flexible vacuum hose. He spent his shift in the clinker cooler area and the top floor of the mill building. For all workers the geometric mean total dust level was 3.31 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. Dust collectors, laborers, bulk loaders, mill helpers, crane operators, and vacuum truck drivers 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 sand (49.2%), shale (24.2%), crushed limestone (1%), dust from raw mill feed areas (1-4.4%), and an oil absorbent which was montmorillite clay(5.7%). Quartz is a common constituent 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 to silicates. All workers associated with raw material dusts are potentially exposed to concentrations of quartz.

Forty respirable dust samples, which were from workers thought to have greater quartz exposure, were analyzed for concentrations of the free crystalline types, quartz and cristobalite. Two samples contained detectable levels of quartz. The laborer was cleaning up in various areas of the plant. The dust collector was hauling waste precipitator dust from the dust bin to the dump.

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 1.7 - 3.0%.

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.

Both samples exceed the permissible exposure limit, and contained concentrations of quartz greater than 100 ug/m^3 . Exposures below this level have been suggested in past research as safe levels of exposure. (9,10,11)

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. Area total dust samples were collected throughout the plant and analyzed for the same six trace metals. Although we attempted to place the area samples in locations representative of work areas, these stationary samples should not be considered estimates of personal exposure. Their purpose is to document the presence of these metals in airborne particulates and their relative concentrations. Aluminum and magnesium are commonly found in the dust particles. Manganese, chromium, cobalt, and nickel are occasionally found. 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.

The four samples analyzed by ICP-AES were also for purposes of documenting the presence of these metals in airborne particulates and their relative concentrations. The metals primarily found in all the dust types are: aluminum, calcium, iron, magnesium, and sodium.

Asbestos

In this survey we found no asbestos present in the raw materials. NIOSH has surveyed quarries and raw materials associated with cement plants, as well as other limestone quarries. No asbestos has been found during any of these surveys. It is possible that quarried rock may be contaminated with asbestos fibers due to the occurrence of small deposits of asbestos-bearing rock in the overburden or the quarried strata. If this occurs at all, we expect it to be extremely rare.

Oxides of Sulfur

A sulfur dioxide concentration of 0.14 ppm was found 200 yards east of the plant, where an inversion was pushing stack emissions down into the yard area. This level is below the NIOSH recommended standard of 0.5 ppm, ACGIH TLV of 2 ppm, and MSHA PEL of 5 ppm. This measurement shows however that exposure to sulfur dioxide may occur. Exposures to greater concentrations may occur because of breakdowns or breaches in the kiln exhaust system. Also, if the sulfur content of the kiln fuel increases, more sulfur dioxide may be

produced. Sulfate particulates have not been documented to cause irritation or chronic disease. However, there is strong evidence that aerosols of these water soluble salts catalyze the conversion of sulfur dioxide to sulfuric acid, thus potentiating the irritant and reflex bronchoconstrictive effects of sulfur dioxide. (14) Nevertheless, workers should not experience irritation or respiratory changes attributable to SO_2 or sulfates at levels detected at Lehigh. (1, 12, 13)

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. (22)

Based on animal studies, a ceiling limit (the concentrations, not to be exceeded even instantaneously) of 5 ppm has been recommended. (23) 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). (24) This was based upon the ACGIH TLV except that the ceiling designation was omitted. (27) 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.

(25,26,27,28) 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 30 samples taken at Lehigh Cement were below the recommended standard.

Toxic Gases

No sulfur dioxide was detected at the coal stoker of the raw mills or the feed area for the kilns. Above the coal stoker 5 ppm carbon monoxide was detected. In the cab of a quarry truck which was making a routine hauling cycle, 0.5 to 1.0 ppm of oxides of nitrogen were detected. Carbon monoxide, oxides of nitrogen, and sulfur dioxide are common contaminants in exhaust gases from the burning of fossil fuels. Portland cement plants have several areas which may be contaminated with these exhaust gases. At this facility the kilns are fired with pulverized coal. When coal, a carbonaceous material containing sulfur and nitrogen compounds, is burned in the kilns, these gases are produced. Gasoline and diesel powered engines of locomotives, quarry equipment, transport trucks, and forklifts release carbon monoxide and oxides of nitrogen in their exhaust. It is our judgement, barring unforeseen mechanical or maintenance problems, that the workers are exposed to very low or insignificant levels of these gases.

Ammonia was detected in concentrations of 2.0-2.5 ppm in the breathing zone of lab workers while analyzing cement samples by wet chemical techniques.

Although concentrations may be somewhat higher instantaneously, exposure lasts for no more than 5-15 minutes, only once or twice during a shift. There should be no irritative problems at these levels of ammonia.

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. 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 Lehigh Cement Plant in Mitchell, Indiana are below recommended exposure levels. One respirable sample from a dust collector exceeded the ACGIH recommended level for respirable nuisance particulate. Three total dust samples, from a crane operator, vacuum truck driver, and mill halper, exceeded the 10 mg/m^3 MSHA standard for total nuisance dust. Two respirable dust samples from a laborer

and a dust collector contained detectable levels of quartz. Both 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.

Recommendations

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.

Measurements detecting overexposures from the dust collectors, vacuum truck driver, laborers, and mill helper were of workers involved in maintenance or clean-up operations. It is difficult to implement controls to protect workers involved in these types of operations since their duties may take them into non-routine work stations. In these cases, workers may need to be provided with personal protective devices. However, the crane operator is enclosed in a stationary position. The crane cab could be modified with tighter seals and an air filtering ventilation system to reduce dust levels inside the cab. We recommend that these jobs be periodically monitored to assure compliance to respirable and total dust and crystalline silica standards.

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.

References

1. Caplan, K., Doemeny, L., Sorensen, S. "Performance Characteristics of the 10 mm cyclone respirable mass sampler," American Industrial Hygiene Assoc. Journal, Vol. 38, Feb. 77, p. 87.
2. NIOSH Manual of Analytical Methods. "Free Silica (Quartz, Cristobalite, Tridymite) in Airborne Dust," 2nd Edition, USDHEW Publication, 1977, P & CAM 259.
3. NIOSH Manual of Analytical Methods. "General Procedure for Metals, " P & CAM 173.
4. NIOSH Manual of Analytical Methods. "Trace Elements", Volume 7, P & CAM 351, 1981.
5. NIOSH Manual of Analytical Methods. "Asbestos Fiber in Air," P & CAM 239.
6. NIOSH Manual of Analytical Methods. "Sulfates, Sulfites, and Sulfur Dioxide," Volume 5, P & CAM 268.
7. Olishifski, J., Fundamentals of Industrial Hygiene, 2nd Edition, National Safety Council, 1979.
8. American Conference of Governmental Industrial Hygienists, Documentation of the Threshold Limit Values, Fourth Edition, Cincinnati, Ohio, 1980.
9. Ayer, H., "The Proposed ACGIH Mass Limits for Quartz: Review and Evaluation," American Industrial Hygiene Journal, 30: 117, 1969.
10. Hosay, A.D., Ashe, H. and Trasko, V.: "Control of Silicosis in Vermont Granite Industry. PHS Publication 557, Washington, D.C., (1957).
11. Sutton, G.W. and Reno, S.J. "Respirable Mass Concentrations Equivalent to Impinger Count Data, Barre, VT Granite sheds." Presented at 1968 annual meeting, Amer. Ind. Hyg. Assoc., St. Louis, MO.
12. Frank, et. al., Journal of Applied Physiology, 17:252 (1962).
13. Tomono, Y., Japan Journal Industrial Health, 3:77 (1966).
14. Andur, M.O., The Effect of various aerosols on the response of guinea pigs to sulfur dioxide. Archives Environ. Health, 16:460-68, 1968.
15. K. Morgan and A. Seaton. Occupational Lung Diseases, W.B. Saunders Co., 1975.

16. American Conference of Governmental Industrial Hygienists. "TLV's for Chemical Substances and Physical Agents in the Workroom Environment," 1980.
17. U.S. Department of Health Education and Welfare. "Pocket Guide to Chemical Hazards," Sept. 1978.
18. Snedecor, W. and Cochran, G., Statistical Methods, 6th Edition, Iowa State University, Ames, Iowa. 1974.
19. Hatch, T.F. "Developments in the Sampling of Airborne Dust," Archives Industrial Hygiene and Occupational Med., 11:212-217 (1955).
20. Palmes, E; et al., Personal Sampler for Nitrogen Dioxide, Am. Ind. Hygiene Assoc. J., Oct. 1976; vol. 37; 570-577.
21. Hearl, F. Industrial Hygiene Studies of Diesel Emissions in Coal Mines, NIOSH, 1981.
22. NIOSH: Occupational Exposure to Oxides of Nitrogen, Criteria for a Recommended Standard. National Institute for Occupational Safety and Health, 1976.
23. ACGIH, Threshold Limit Values, 4th ed., Cincinnati, OH, 1980.
24. 29 CFR 1910.1000, published in the Federal Register, 39: 23642, June 27, 1974.
25. Von Nieding, G., et. al., Protective action of atropine neclastine & occiprenaline on provocation tests with NO₂ in health subjects and patients with chronic non-specific bronchitis, In Arch. Arbeitsmed, 29:55-63, 1971.
26. Von Nieding, et al., Studies of the acute effects of NO₂ on lung function, influence on diffusion, perfusion, and ventilation in the lungs, Int. Arch. Arbeitsmed, 31:61-72, 1975.
27. Kosnider, S., et al., Zentralbl. Arbeitsmed. 22:362, 1972
28. Vigdortschik, N., et al., J. Ind. Hyg. & Tox., 19:469, 1937.

Table 1

Environmental Investigations Branch

Industrial Hygiene Survey of Cement Workers
Lehigh Cement, Mitchell, Indiana

Number of Samples With Detectable Levels of Contaminants

<u>Contaminant</u>	<u># Samples Collected</u>	<u># Samples with Detectable Conc.</u>	<u>Limit of Detection</u>
Respirable dust	56	56	0.01 mg
Total dust	13	13	0.01 mg
Quartz	40	2	0.03 mg
Cristobalite	40	0	0.03 mg
Aluminum	32	13	0.20 mg
Chromium	32	2	0.004 mg
Cobalt	32	2	0.005 mg
Magnesium	32	28	0.002 mg
Manganese	32	2	0.002 mg
Nickel	32	3	0.004 mg
Asbestos	13	0	4500 fibers
Sulfate	6	6	0.005 mg
Sulfite	6	3	0.01 mg
Sulfur dioxide	6	1	0.005 mg
Nitrgen dioxide	30	30	0.02 ppm

Table 2

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LEHIGH CEMENT MITCHELL, INDIANA
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
GROUPED BY EXPOSURE AREA

----- AREA=BACKGROUND -----

JOB	DATE	SHIFT	DUSTMG/M3
BACKGROUND	18NOV81	2	0.01
BACKGROUND	19NOV81	1	0.17
BACKGROUND	20NOV81	1	0.01
BACKGROUND	23NOV81	1	0.01

----- AREA=RAM -----

JOB	DATE	SHIFT	DUSTMG/M3
FRONT END LOADER	19NOV81	1	0.17
PRIMARY CRUSHER OPERATOR	19NOV81	1	1.19
CONVEYOR OPERATOR	19NOV81	1	0.85
MECHANIC (QUARRY)	20NOV81	1	0.65
FRONT END LOADER	20NOV81	1	0.12
DRILLER	20NOV81	1	0.69
DRILLER	23NOV81	1	0.24
QUARRY TRUCK DRIVER	23NOV81	1	0.77
QUARRY TRUCK DRIVER	23NOV81	1	0.76

----- AREA=CLINKER -----

JOB	DATE	SHIFT	DUSTMG/M3
KILN HELPER	18NOV81	2	0.37
KILN BURNER	18NOV81	2	0.05
KILN HELPER	18NOV81	2	0.50
VACUUM TRUCK DRIVER	20NOV81	1	1.50
KILN BURNER	20NOV81	1	0.19
KILN HELPER	20NOV81	1	0.69
KILN HELPER	20NOV81	3	0.71
KILN HELPER	23NOV81	1	2.36

----- AREA=FINISH -----

JOB	DATE	SHIFT	DUSTMG/M3
LOCOMOTIVE OPERATOR	19NOV81	1	0.74
BULK LOADER	19NOV81	1	2.78
LOCOMOTIVE OPERATOR	19NOV81	1	0.85
BULK LOADER	19NOV81	1	1.64

Table 2

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LEHIGH CEMENT HITCHELL, INDIANA
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
GROUPED BY EXPOSURE AREA

----- AREA=MIX -----

JOB	DATE	SHIFT	DUST/MG/M3
SHIFT FOREMAN	18NOV81	2	0.14
HILL HELPER (MIX)	18NOV81	2	0.64
HILL HELPER (MIX)	18NOV81	2	0.52
CRANE OPERATOR	18NOV81	2	1.29
HILL OPERATOR	18NOV81	2	0.37
MIX CHEMIST	18NOV81	2	0.38
OILER (GENERAL)	19NOV81	1	0.34
CRANE OPERATOR	19NOV81	1	0.26
HILL HELPER (MIX)	19NOV81	1	0.93
YARD WORKERS	19NOV81	1	0.18
SHIFT FOREMAN	19NOV81	1	0.28
REPAIRMAN	19NOV81	1	0.55
MACHINIST	19NOV81	1	0.10
UTILITY (SHIFT)	19NOV81	1	1.41
JANITOR	20NOV81	1	0.25
WELDER	20NOV81	1	0.29
REPAIRMAN	20NOV81	1	0.28
ELECTRICIAN	20NOV81	1	0.66
LABORATORY WORKER	20NOV81	1	1.58
LOCOMOTIVE OPERATOR	20NOV81	1	0.52
YARD WORKERS	20NOV81	1	0.91
HILL OPERATOR	20NOV81	1	2.54
LOCOMOTIVE OPERATOR	20NOV81	1	1.16
HILL HELPER (MIX)	20NOV81	3	2.49
HILL OPERATOR	20NOV81	3	2.20
CRANE OPERATOR	20NOV81	3	1.20
SHIFT FOREMAN	20NOV81	3	2.27
LABORATORY WORKER	20NOV81	3	1.80
REPAIRMAN	23NOV81	1	1.19
LABORER	23NOV81	1	1.09
LADDER	23NOV81	1	3.91
DUST COLLECTOR	23NOV81	1	10.43
REPAIRMAN	23NOV81	1	1.38
LABORER	23NOV81	1	0.77
REPAIRMAN	23NOV81	1	0.76

Table 3

ENVIRONMENTAL INVESTIGATIONS BRANCH
 CEMENT WORKERS MORBIDITY STUDY
 LEHIGH CEMENT HITCHELL, INDIANA
 PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3

AREA	SAMPLES	MEAN	STD	GM	GSD	NLOD	MIN	MAX
BACKGROUND	4	0.05	0.08	0.02	4.15	0	0.01	0.17
RAW	9	0.61	0.36	0.48	2.24	0	0.12	1.19
CLINKER	8	0.80	0.77	0.48	3.37	0	0.05	2.36
FINISH	4	1.50	0.94	1.30	1.85	0	0.74	2.78
MIX	35	1.29	1.81	0.77	2.73	0	0.10	10.43
PLANTWIDE	56	1.13	1.50	0.69	2.72	0	0.05	10.43

ENVIRONMENTAL INVESTIGATIONS BRANCH
 CEMENT WORKERS MORBIDITY STUDY
 LEHIGH CEMENT HITCHELL, INDIANA
 PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
 ARITHMETIC MEAN VALUES BY AREA

BAR CHART OF MEANS

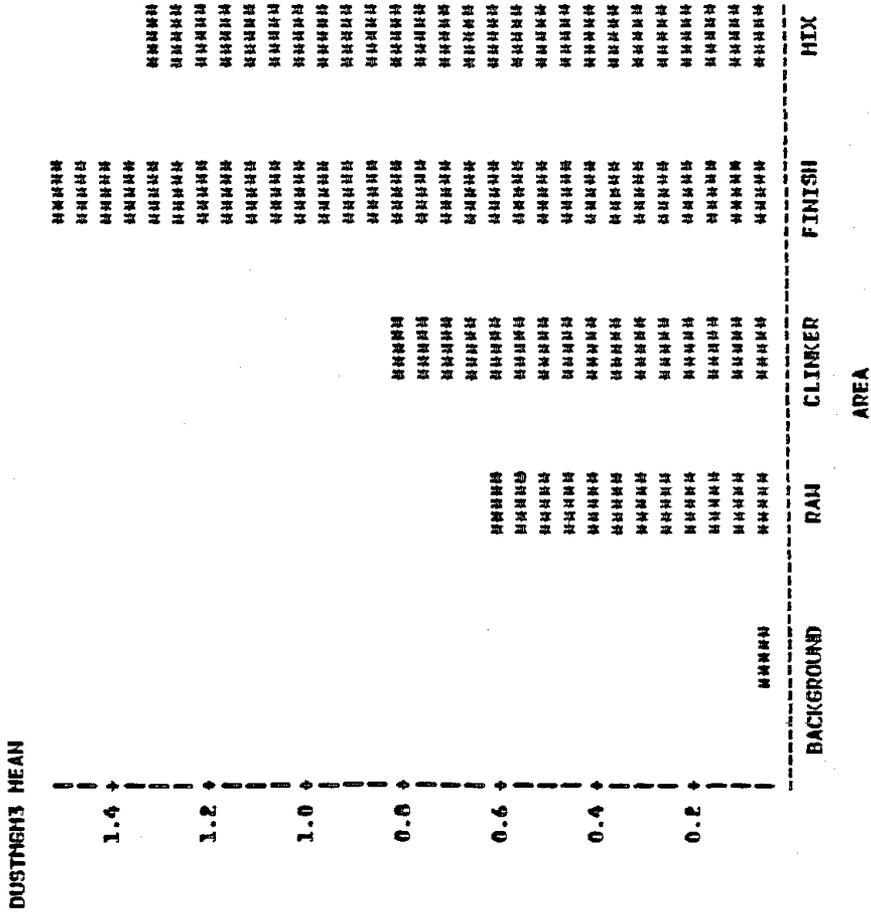


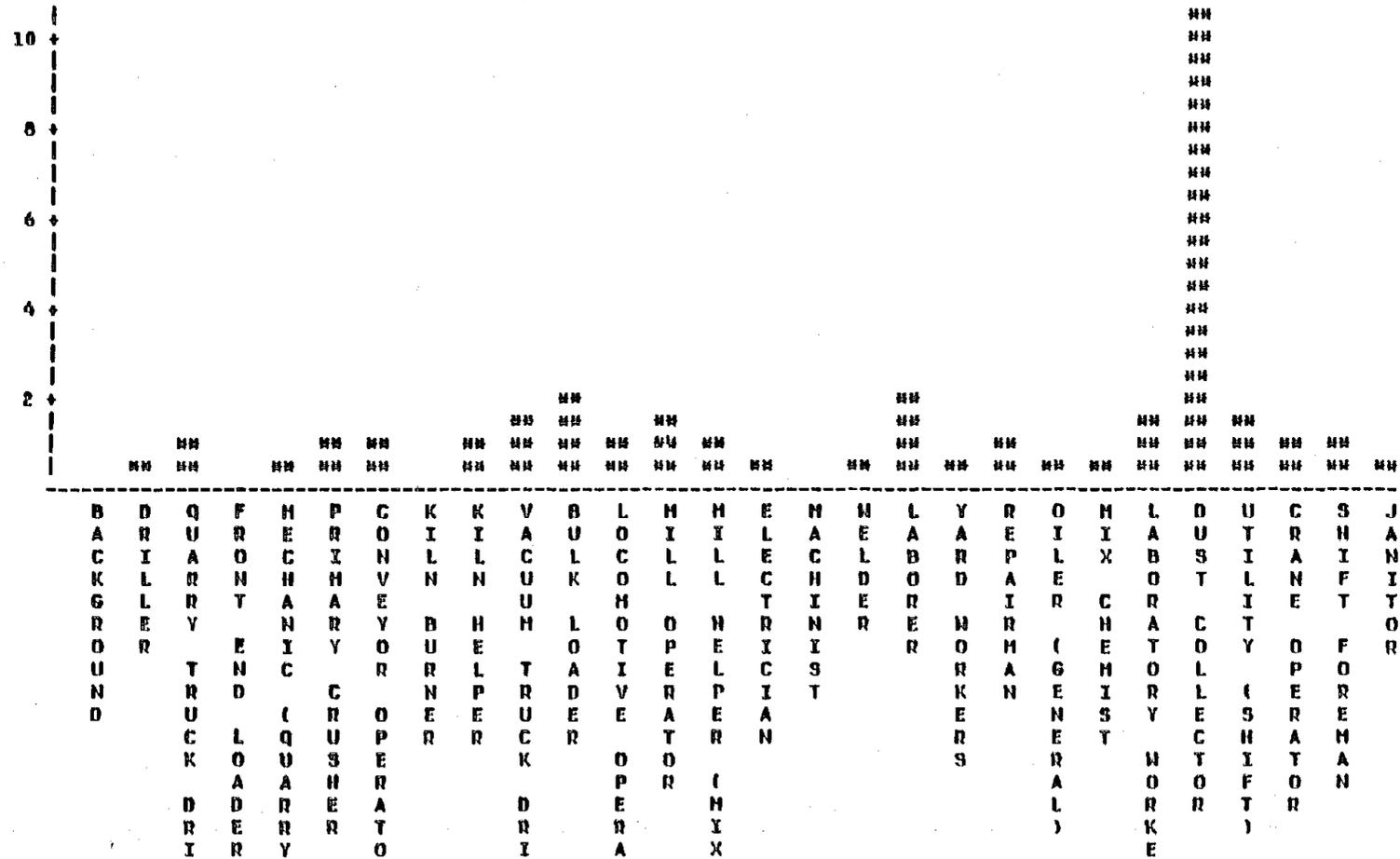
Figure 2

Figure 3

ENVIRONMENTAL INVESTIGATIONS BRANCH
 CEMENT WORKERS MORBIDITY STUDY
 LEHIGH CEMENT HITCHELL, INDIANA
 PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
 ARITHMETIC MEAN VALUES BY JOB CATEGORY

BAR CHART OF MEANS

DUSTMG/M3 MEAN



JOB

Table 4

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LEHIGH CEMENT HITCHELL, INDIANA
QUARTZ CONCENTRATION OF PERSONAL RESPIRABLE DUST SAMPLES
QUARTZ CONCENTRATION IN MICROGRAMS PER CUBIC METER (UG/M3)

JOB	DATE	SHIFT	PCT_SIO2	QUARTZ	AREA
PRIMARY CRUSHER OPERATOR	19NOV81	1	N	N	RAW
CONVEYOR OPERATOR	19NOV81	1	N	N	RAW
FRONT END LOADER	19NOV81	1	N	N	RAW
FRONT END LOADER	20NOV81	1	N	N	RAW
DRILLER	20NOV81	1	N	N	RAW
QUARRY TRUCK DRIVER	23NOV81	1	N	N	RAW
DRILLER	23NOV81	1	N	N	RAW
QUARRY TRUCK DRIVER	23NOV81	1	N	N	RAW
VACUUM TRUCK DRIVER	20NOV81	1	N	N	CLINKER
KILN HELPER	23NOV81	1	N	N	CLINKER
BULK LOADER	19NOV81	1	N	N	FINISH
LOCOMOTIVE OPERATOR	19NOV81	1	N	N	FINISH
BULK LOADER	19NOV81	1	N	N	FINISH
HILL OPERATOR	18NOV81	2	N	N	MIX
HILL HELPER (MIX)	18NOV81	2	N	N	MIX
HILL HELPER (MIX)	18NOV81	2	N	N	MIX
CRANE OPERATOR	18NOV81	2	N	N	MIX
REPAIRMAN	19NOV81	1	N	N	MIX
CRANE OPERATOR	19NOV81	1	N	N	MIX
HILL HELPER (MIX)	19NOV81	1	N	N	MIX
UTILITY (SHIFT)	19NOV81	1	N	N	MIX
OILER (GENERAL)	19NOV81	1	N	N	MIX
LABORATORY WORKER	20NOV81	1	N	N	MIX
ELECTRICIAN	20NOV81	1	N	N	MIX
HILL HELPER (MIX)	20NOV81	3	N	N	MIX
HILL OPERATOR	20NOV81	1	N	N	MIX
REPAIRMAN	20NOV81	1	N	N	MIX
LOCOMOTIVE OPERATOR	20NOV81	1	N	N	MIX
HILL OPERATOR	20NOV81	3	N	N	MIX
CRANE OPERATOR	20NOV81	3	N	N	MIX
LOCOMOTIVE OPERATOR	20NOV81	1	N	N	MIX
LABORATORY WORKER	20NOV81	3	N	N	MIX
YARD WORKERS	20NOV81	1	N	N	MIX
SHIFT FOREMAN	20NOV81	3	N	N	MIX
LABORER	23NOV81	1	N	N	MIX
LABORER	23NOV81	1	3.0	116.95	MIX
DUST COLLECTOR	23NOV81	1	1.7	176.72	MIX
REPAIRMAN	23NOV81	1	N	N	MIX
LABORER	23NOV81	1	N	N	MIX
REPAIRMAN	23NOV81	1	N	N	MIX

Table 5

Environmental Investigations Branch
 Industrial Hygiene Survey of Cement Workers
 Lehigh Cement, Mitchell, Indiana

Detectable Quartz Compared to MSHA Permissible Exposure Levels

Job	Levels of Dust Conc. Mg/m ³	Quartz Conc.		MSHA PEL mg/m ³
		% Quartz	ug/m ³	
Laborer	3.91*	3.0	116.95	2.0
Dust Collector	10.43*	1.7	176.72	2.7

*Indicates measured concentration exceeds the MSHA Permissible Exposure Limit.

Table 6

ENVIRONMENTAL INVESTIGATIONS BRANCH
 CEMENT WORKERS MORBIDITY STUDY
 LEHIGH CEMENT MITCHELL, INDIANA
 PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3
 GROUPED BY EXPOSURE AREA

----- AREA=BACKGROUND -----

JOB	DATE	SHIFT	DUSTMG/M3
BACKGROUND	19NOV81	1	0.40
BACKGROUND	20NOV81	1	0.99
BACKGROUND	23NOV81	1	0.00

----- AREA=RAW -----

JOB	DATE	SHIFT	DUSTMG/M3
ELECTRICIAN (RAW)	19NOV81	1	2.87
QUARRY TRUCK DRIVER	19NOV81	1	1.06
CONVEYOR OPERATOR	20NOV81	1	3.05
PRIMARY CRUSHER OPERATOR	20NOV81	1	2.35
FRONT END LOADER	20NOV81	1	0.26
HILL HELPER (RAW)	20NOV81	1	5.89

----- AREA=CLINKER -----

JOB	DATE	SHIFT	DUSTMG/M3
KILN HELPER	23NOV81	1	6.00

----- AREA=MIX -----

JOB	DATE	SHIFT	DUSTMG/M3
INSTRUMENT DEPARTMENT	19NOV81	1	1.68
MACHINIST	19NOV81	1	0.98
PAINTER	23NOV81	1	5.75
HILL HELPER (MIX)	23NOV81	1	10.42
CRANE OPERATOR	23NOV81	1	19.79
VACUUM TRUCK DRIVER	23NOV81	1	12.66

Table 7

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LEHIGH CEMENT MITCHELL, INDIANA
PERSONAL TOTAL DUST CONCENTRATIONS, HG/M³

AREA	SAMPLES	MEAN	STD	GH	GSD	NLOD	MIN	MAX
BACKGROUND	3	0.47	0.49	0.12	18.47	0	0.00	0.99
RAW	6	2.50	1.95	1.80	2.98	0	0.26	5.89
CLINKER	1	6.00	.	6.00	.	0	6.00	6.00
MIX	6	0.50	7.16	5.50	3.23	0	0.90	19.79
PLANTWIDE	13	5.61	5.65	3.31	3.28	0	0.26	19.79

Figure 4

ENVIRONMENTAL INVESTIGATIONS BRANCH
 CEMENT WORKERS MORBIDITY STUDY
 LEHIGH CEMENT HITCHELL, INDIANA
 PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3
 ARITHMETIC MEAN VALUES BY AREA

BAR CHART OF MEANS

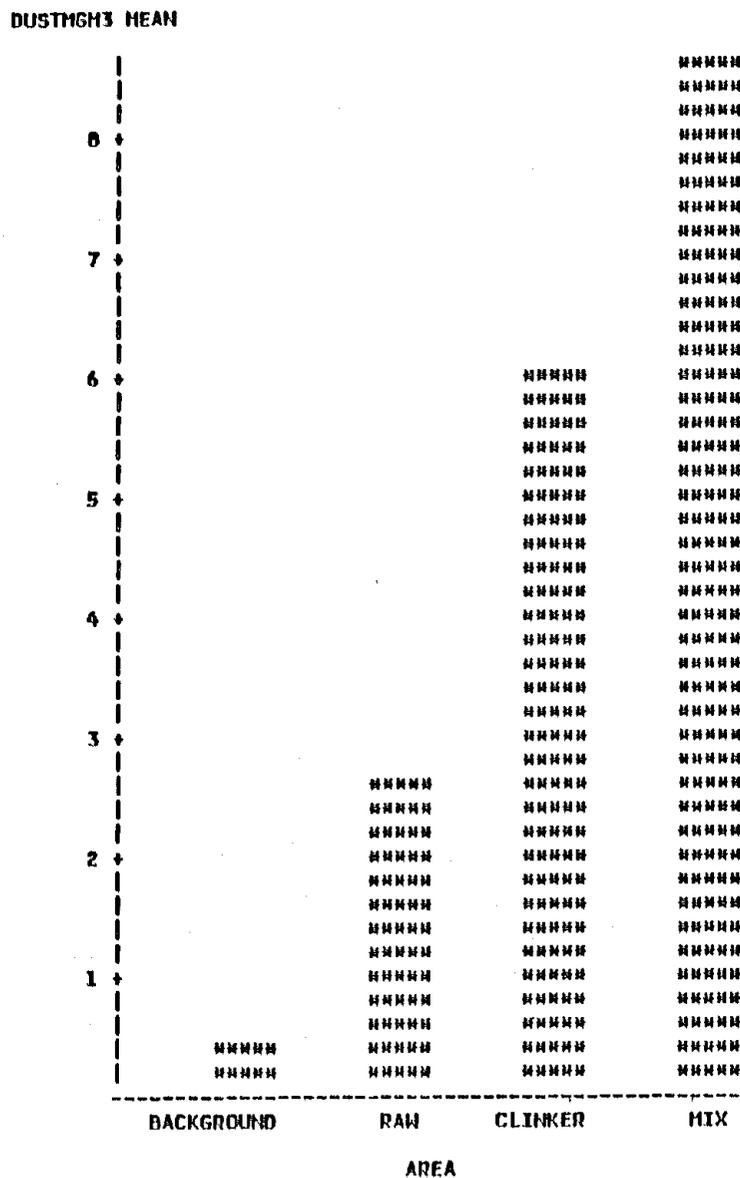
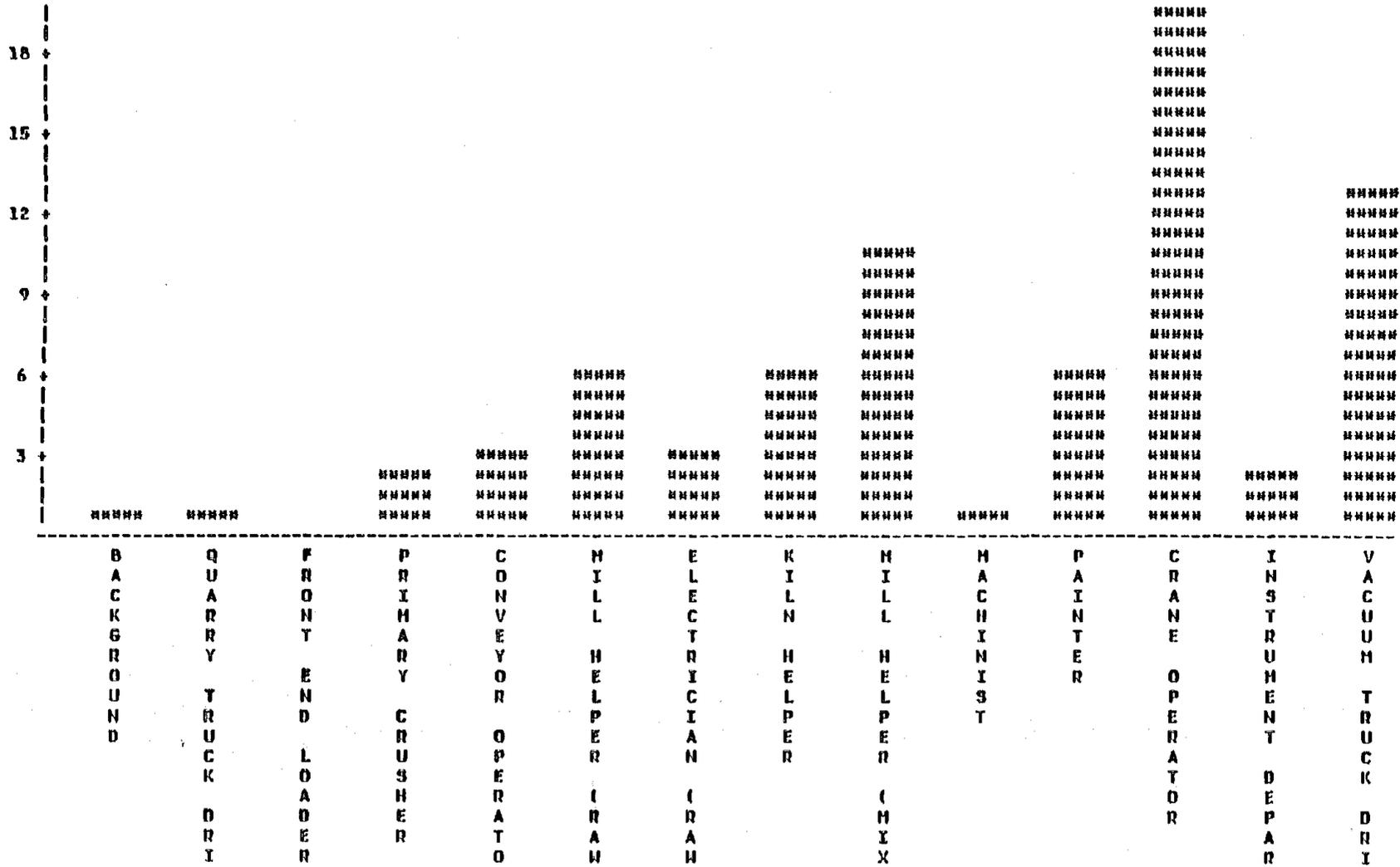


Figure 5

ENVIRONMENTAL INVESTIGATIONS BRANCH
 CEMENT WORKERS MORBIDITY STUDY
 LEHIGH CEMENT MITCHELL, INDIANA
 PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3
 ARITHMETIC MEAN VALUES BY JOB CATEGORY

BAR CHART OF MEANS

DUST/MG/M3 MEAN



JOB

Table 8

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LEHIGH CEMENT MITCHELL, INDIANA
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	19NOV81	1	ELECTRICIAN (RAW)	30	N	N	24	N	N
RAW	19NOV81	1	QUARRY TRUCK DRIVER	N	N	N	4	N	N
RAW	20NOV81	1	FRONT END LOADER	N	N	N	N	N	5
RAW	20NOV81	1	HILL HELPER (RAW)	85	N	N	53	N	N
RAW	20NOV81	1	PRIMARY CRUSHER OPERATOR	N	N	N	12	N	N
RAW	20NOV81	1	CONVEYOR OPERATOR	N	N	N	17	N	N
CLINKER	23NOV81	1	KILN HELPER	96	N	N	60	N	N
MIX	19NOV81	1	MACHINIST	N	N	N	3	N	N
MIX	19NOV81	1	INSTRUMENT DEPARTMENT	N	N	N	9	N	N
MIX	20NOV81	1	WELDER	970	728	12	582	1698	412
MIX	23NOV81	1	HILL HELPER (MIX)	147	N	N	93	N	N
MIX	23NOV81	1	CRANE OPERATOR	335	N	N	264	N	N
MIX	23NOV81	1	PAINTER	68	N	N	113	N	N
MIX	23NOV81	1	VACUUM TRUCK DRIVER	172	N	N	132	N	N

Table 9

Environmental Investigations Branch
Industrial Hygiene Survey of Cement Workers
Lehigh Cement, Mitchell, Indiana

Summary for Personal Trace Metal Concentrations in
Micrograms per Cubic Meter ($\mu\text{g}/\text{m}^3$)

<u>Metal</u>	<u>N</u>	<u>Means</u>	<u>Std.dev.</u>	<u>Minimum</u>	<u>Maximum</u>
Aluminum	8	239	309.62	38	970
Chromium	1	728	--	728	728
Cobalt	1	12	--	12	12
Magnesium	13	105	161.04	3	582
Manganese	1	1698	--	1698	1698
Nickel	2	209	288.26	5	412

Table 10

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LEHIGH CEMENT HITCHELL, INDIANA
TRACE METAL CONCENTRATIONS OF AREA TOTAL DUST SAMPLES
CONCENTRATIONS IN MICROGRAMS PER CUBIC METER (UG/M3)

AREA	DATE	SHIFT	JOB	AL_UGM3	CR_UGM3	CO_UGM3	MG_UGM3	HM_UGM3	NI_UGM3
BACKGROUND	19NOV81	1	BACKGROUND	N	N	N	N	N	N
BACKGROUND	20NOV81	1	BACKGROUND	N	N	N	N	N	N
BACKGROUND	23NOV81	1	BACKGROUND	N	N	N	N	N	N
RAW	18NOV81	2	BACK END OF KILN	N	N	N	N	N	N
RAW	19NOV81	1	PRIMARY CRUSHER	N	N	N	9	N	N
RAW	23NOV81	1	FEED END RAW MILLS	N	N	N	20	N	N
CLINKER	18NOV81	2	FRONT END OF KILN	N	N	N	6	N	N
CLINKER	18NOV81	2	CLINKER COOLER	110	N	N	81	N	N
CLINKER	20NOV81	1	CLINKER COOLER	N	N	N	20	N	N
CLINKER	23NOV81	1	CLINKER COOLER	447	N	N	369	N	N
FINISH	19NOV81	1	BULK LOADING SILOS	N	N	N	16	N	N
FINISH	20NOV81	1	FINISH BALL MILLS	130	N	N	83	N	N
FINISH	20NOV81	1	BULK LOADING SILOS	N	N	N	13	N	N
FINISH	23NOV81	1	BULK LOADING SILOS	N	N	N	10	N	N
HIX	18NOV81	2	MILL ROOM	N	N	N	7	N	N
HIX	19NOV81	1	MAINTENANCE SHOP	N	N	N	1	N	N
HIX	19NOV81	1	OVERHEAD CRANE	93	N	N	55	N	N
HIX	23NOV81	1	MILL ROOM	N	N	N	34	N	N

Table 11

Environmental Investigations Branch
Industrial Hygiene Survey of Cement Workers
Lehigh Cement, Mitchell, Indiana

Summary for Area Trace Metal Concentrations in
Micrograms per Cubic Meter ($\mu\text{g}/\text{m}^3$)

<u>Metal</u>	<u>N</u>	<u>Means</u>	<u>Std. Dev.</u>	<u>Minimum</u>	<u>Maximum</u>
Aluminum	4	197	167.62	93	447
Magnesium	14	52	95.28	1	369

Table 12

Environmental Investigations Branch
 Industrial Hygiene Survey of Cement Workers
 Lehigh Cement, Mitchell, Indiana

Trace Metals Concentrations as Measured by ICP-AES
 Concentrations in Micrograms per Cubic Meter ($\mu\text{g}/\text{m}^3$)

<u>Metals</u>	<u>Exposure Categories</u>			
	<u>Mill Rm. Grey Plant</u>	<u>Clinker-Cooler Grey</u>	<u>Bagging White Plant</u>	<u>Finish & Clinker Cooler White Plant</u>
Aluminum	505.3	19.7	94.6	1415.4
Calcium	13102.6	705.3	1702.3	35230.8
Chromium	3.42	N	N	N
Iron	571.1	24.5	84.9	1484.6
Lithium	3.16	N	N	9.23
Magnesium	318.4	16.3	59.3	1161.5
Manganese	4.7	N	N	15.38
Sodium	49.13	7.8	22.1	125.15
Phosphorus	N	N	N	N
Lead	N	N	N	15.4
Titanium	30.3	N	5.1	70.0
Zinc	3.2	N	N	N

The following elements were analyzed for, but were less than 0.5 $\mu\text{g}/\text{filter}$ in all samples: silver, arsenic, beryllium, cadmium, cobalt, copper, molybdenum, nickel, platinum, selenium, tin, tellurium, thallium, vanadium, yttrium, and zirconium.

Table 13

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
LEHIGH CEMENT MITCHELL, INDIANA
ANALYSIS OF BULK MATERIAL PRESENTED AS PERCENT BY HEIGHT

AREA	JOB	QUARTZ	CRISTB	AL	CR	CO	HG	MN	NI	ASBEST
RAW	RAW MATERIAL	4.4	N	1.60	N	0.009	0.92	0.013	0.007	0.0
RAW	RAW MATERIAL	24.2	N	5.10	0.004	0.006	0.46	0.012	0.007	0.0
RAW	RAW MATERIAL	1.0	N	0.30	N	0.008	0.65	0.008	0.005	0.0
RAW	RAW MATERIAL	N	N	6.90	0.008	0.009	0.28	0.021	0.011	0.0
RAW	RAW MATERIAL	49.2	N	0.30	N	N	1.30	0.026	N	0.0
RAW	RAW MATERIAL	1.0	N	1.80	0.004	0.010	1.10	0.013	0.008	0.0
RAW	RAW MATERIAL	1.0	N	1.90	0.005	0.010	1.10	0.012	0.008	0.0
RAW	RAW MATERIAL	N	N	0.13	N	0.008	0.46	0.010	0.006	0.0
RAW	RAW MATERIAL	1.0	N	0.33	N	0.009	1.10	0.008	0.006	0.0
RAW	RAW MATERIAL	N	N	0.17	N	0.008	0.55	0.007	0.006	0.0
RAW	RAW MATERIAL	1.0	N	0.14	N	0.009	0.85	0.008	0.006	0.0
CLINKER	CLINKER	N	N	2.20	0.006	0.011	1.20	0.011	0.009	0.0
CLINKER	CLINKER	N	N	2.30	0.006	0.012	1.20	0.011	0.009	0.0
CLINKER	CLINKER	N	N	2.50	0.004	0.012	1.10	0.011	0.009	0.0
CLINKER	CLINKER	N	N	2.10	0.008	0.013	1.30	0.011	0.010	0.0
FINISH	FINISH	N	N	2.60	0.005	0.012	1.40	0.015	0.009	0.0
FINISH	FINISH	N	N	2.60	0.005	0.013	1.40	0.014	0.009	0.0
FINISH	FINISH	N	N	2.70	0.003	0.012	1.50	0.014	0.009	0.0
FINISH	FINISH	N	N	2.70	0.004	0.012	1.50	0.014	0.008	0.0
MIX	RAW CLINKER FINISH	N	N	2.50	0.005	0.012	1.30	0.013	0.009	0.0
RAW	ABSORBENT	5.7	N	4.20	0.015	0.004	0.96	0.008	N	0.0

Table 14

ENVIRONMENTAL INVESTIGATIONS BRANCH
 CEMENT WORKERS MORBIDITY STUDY
 LEHIGH CEMENT MITCHELL, INDIANA
 SOX CONCENTRATIONS

JOB	DATE	SHIFT	AREA	SO4_UGM3	SO3_UGM3	SO2_PPM
BACK END OF KILN	18NOV81	2	RAW	11.33	N	0.01
BACK END OF KILN	19NOV81	1	RAW	24.65	N	N
BACK END OF KILN	19NOV81	1	RAW	24.65	N	N
YARD	20NOV81	1	HIX	49.03	24.51	0.14
OVERHEAD CRANE	20NOV81	1	HIX	61.63	N	N
YARD	20NOV81	1	HIX	53.93	34.32	0.14

Table 15

ENVIRONMENTAL INVESTIGATIONS BRANCH
 CEMENT WORKERS MORBIDITY STUDY
 LEHIGH CEMENT MICHNELL, INDIANA
 NO2 CONCENTRATIONS IN PPM

JOB	DATE	SHIFT	AREA	CONC
BACKGROUND	19NOV81	1	BACKGROUND	0.10
BACKGROUND	20NOV81	1	BACKGROUND	0.03
FRONT END LOADER	19NOV81	1	RAW	0.04
PRIMARY CRUSHER OPERATOR	19NOV81	1	RAW	0.04
CONVEYOR OPERATOR	19NOV81	1	RAW	0.04
MECHANIC (QUARRY)	20NOV81	1	RAW	0.07
FRONT END LOADER	20NOV81	1	RAW	0.04
DRILLER	20NOV81	1	RAW	0.03
VACUUM TRUCK DRIVER	20NOV81	1	CLINKER	0.10
KILN BURNER	20NOV81	1	CLINKER	0.03
KILN HELPER	20NOV81	1	CLINKER	0.04
REBRICKER	20NOV81	1	CLINKER	0.09
LOCOMOTIVE OPERATOR	19NOV81	1	FINISH	0.07
BULK LOADER	19NOV81	1	FINISH	0.11
LOCOMOTIVE OPERATOR	19NOV81	1	FINISH	0.06
BULK LOADER	19NOV81	1	FINISH	0.08
OILER (GENERAL)	19NOV81	1	MIX	0.04
CRANE OPERATOR	19NOV81	1	MIX	0.03
HILL HELPER (MIX)	19NOV81	1	MIX	0.03
YARD WORKERS	19NOV81	1	MIX	0.04
SHIFT FOREMAN	19NOV81	1	MIX	0.04
REPAIRMAN	19NOV81	1	MIX	0.14
MACHINIST	19NOV81	1	MIX	0.04
UTILITY (SHIFT)	19NOV81	1	MIX	0.06
JANITOR	20NOV81	1	MIX	0.03
WELDER	20NOV81	1	MIX	0.04
REPAIRMAN	20NOV81	1	MIX	0.07
ELECTRICIAN	20NOV81	1	MIX	0.09
LABORATORY WORKER	20NOV81	1	MIX	0.04
LOCOMOTIVE OPERATOR	20NOV81	1	MIX	0.07
YARD WORKERS	20NOV81	1	MIX	0.04
LOCOMOTIVE OPERATOR	20NOV81	1	MIX	0.02

Table 16

Environmental Investigations Branch
 Industrial Hygiene Survey of Cement Workers
 Lehigh Cement, Mitchell, Indiana

Direct Reading Indicator Tube Concentrations in
 Parts Per Million (PPM)

Area	Date	SO ₂	CO	NO _x	NH ₃	HCl
Just outside will control room next to coal stoker	Nov. 18	0	0	0		
Feed for kiln #2 and #3		0 0	0 0	0 0		
Inside Quarry truck downhill	Nov. 19		0	0.5	0	
uphill			0	1.0	0	
Truck unload for primary crusher			0			
Next to coal stoker for raw mills	Nov. 23	0	0	0		
2nd floor of mill room above coal stoker			5.0			
In breathing zone of lab worker while analyzing cement samples by wet chemistry	Nov. 23				2.5 2.5 2.0	0 0 0

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.