Industrial Hygiene Survey of Ideal Cement Co.

Okay, Arkansas

Cement Workers Morbidity Study

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Executive Summary

The Ideal Cement Plant in Okay, Arkansas was surveyed by a NIOSH team of industrial hygienists, on April 6 through April 9, 1981. Samples were collected and analyzed for respirable and total dust, free crystalline silica, aluminum, cobalt, magnesium, manganese, nickel, other trace elements, asbestos, and oxides of sulfur.

The respirable and total dust levels for most jobs are below recommended exposure levels. One sample from a conveyor operator exceeded the MSHA PEL for total nuisance particulate. Four respirable dust samples from workers associated with raw materials contained detectable levels of quartz. None of the dust contaminants measured are 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. Ideal Cement in Okay, Arkansas was the eighth 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.

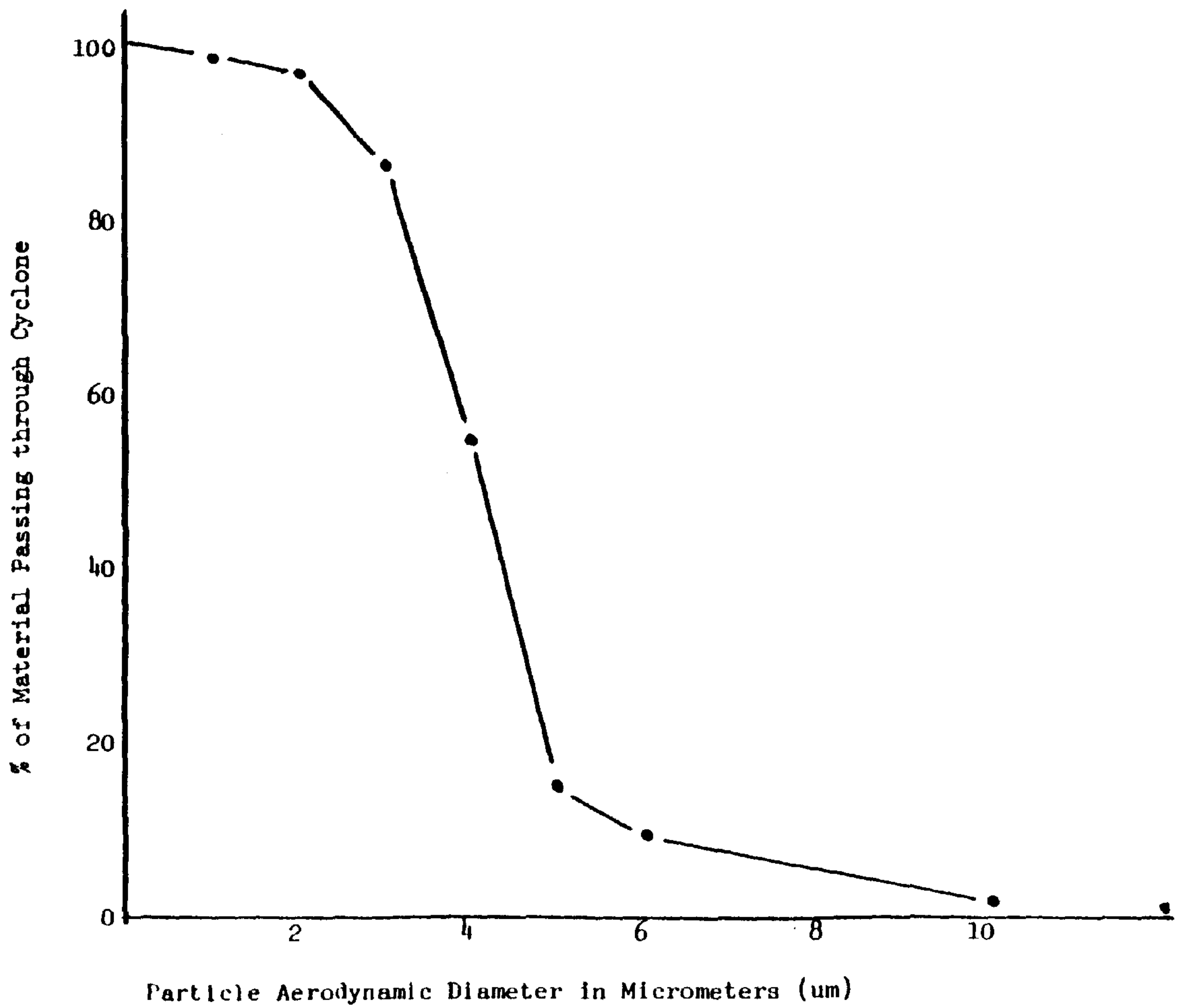
The Ideal Cement plant in Okay, Arkansas was surveyed on Monday, April 6 through Thursday, April 9, 1981, by Doug Pickup, Thomas Wood, Cathy Dewaal, and Wayne Sanderson. The Ideal Cement plant is located near Saratoga, Arkansas along a lake formed by the South Saline and Little Rivers. Cement rock is mined from a quarry adjacent to the plant by dozers, rippers, and scrapers, and sand from a pit a few miles from the plant. Raw materials are crushed, milled, and blended at the plant. Clinkers are manufactured by the wet process method in the original kiln which began operations in 1925, and a second kiln which was added in 1947. Both kilns are fueled by natural gas, except in the winter months when they are fueled by coal. The clinkers are milled in ball mills to increase fineness; this ground material is Portland cement. Four types of finished cement are manufactured at Ideal. The finished cement is bagged or loaded as bulk in trucks or railcars for distribution. Approximately 150 workers are employed here.

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.

Total dust levels are presented in Table 5. These results are summarized in Table 6. 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.

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 ashed in acid and analyzed by atomic absorption for amount of aluminum (Al), chromium (Cr), cobalt (Co), magnesium (Mg), manganese (Mn), and nickel (Ni).

The trace metal concentrations are reported in Table 7 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. 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. The results of the trace metal analyses of the area total samples are summarized in Table 8. 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 these area samples.

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 9. For this analysis technique, the lower limit of detection is 1.0 ug/filter for all elements.

<u>Airborne Fiber Samples</u>

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 lpm. 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.

<u>Bulk Material Samples</u>

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 which exposure category the samples were taken, or whether the material was 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 oxides of sulfur analyses are listed in Table 11. The JOB column tells where the sample was collected. The S04_UGM3 and S03_UGM3 columns give the sulfate and sulfite concentrations in micrograms per cubic meter. The S02_PPM column gives the sulfur dioxide levels in parts per million. No sulfur dioxide or sulfites were detected on any of the samples.

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: (20,21)

$$\text{Conc, ppm} = \frac{\text{nanomoles NO2}}{2.3 \times (\text{Hours of Exposure})}$$

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 12. Nitrogen dioxide is produced from the combustion of nitrogen-containing organic compounds such as coal and diesel fuel.

Direct Reading Indicator Tubes for Toxic Gases

Drager direct reading indicator tubes were used to sample for sulfur dioxide (SO_2), carbon monoxide (CO), chlorine (Cl_2), and oxides of nitrogen (NOX). Air was 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 $\pm$ 25% of the true concentration at levels between one and five times the TLV, and within $\pm$ 35% at 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. Long-term detector tubes for sulfur dioxide were also used in this survey. They operate on the same principle as the short-term tubes, but rather than pulling air through them with a hand-held bellows pump, they are attached to a pump pulling 15-20 ml/min for 6-8 hours. The results of the detector tube samples are listed in Table 13.

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 Monday, April 6, 1981. The sampling schedule was as follows:

Monday, April 6	- 2nd shift
Tuesday, April 7	- 1st shift
Wednesday, April 8	- 1st shift
Thursday, April 9	- 1st shift
Thursday, April 9	- 3rd 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: (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 <u>not</u> 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 precent 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 various jobs, Table 2, none of the samples exceeded 5 mg/m^3. For all workers the geometric mean respirable dust level was 0.25 mg/m^3.

Examining the personal total samples collected from the various jobs, Table 6, one sample exceeded 10 mg/m^3. This sample was worn by a conveyor operator who was shoveling and cleaning up raw material in the primary crusher and dryer area. For all workers the geometric mean total dust level was 2.79 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.

Crystalline Silica

Quartz was detected in bulk samples of raw material (1.7%) and a mixture of raw material and clinker (8.5%). The raw material sample was collected from the raw mill feed table in the mill room, and the mixture sample from settled dust on the overhead crane. 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 into silicates. All workers associated with raw material dust are potentially exposed to concentrations of quartz.

Fifty personal respirable dust samples were analyzed for content of the crystalline mineral types, quartz and cristobalite. Four of the samples contained detectable levels of quartz. All four samples were from workers who had spent all or part of their shift in raw material areas. The raw miller operated and cleaned up areas around the raw mill; the kiln oiler checked and oiled the kiln system from the feed end to the clinker cooler drag chain and elevator; the crane operator moved raw and clinker materials to their appropriate bins; and the electrician worked in many areas of the plant from raw material crushing to the packhouse.

Two of the samples (from the crane operator and the electrician) were not preweighed so a percentage of quartz could not be determined. The sample from the electrician contained a concentration greater than 100 ug/m^3. Exposures below this level have been suggested in past research as safe levels of exposure. (9,10,11)

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.

Trace Metals

Area total dust samples were collected throughout the plant and analyzed for the six trace metals: aluminum, chromium, cobalt, magnesium, manganese, and nickel. 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 is occasionally found. Only one sample contained detectable amounts of chromium. Cobalt and nickel were not detected 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, and magnesium.

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

Only two of eleven samples collected in various areas of the plant contained detectable levels of sulfur dioxide. Sulfur, a common constituent of coal, is oxidized upon combustion to sulfur dioxide. Sulfur dioxide is generally present in the exhausts of kilns fueled by coal. Ideal cement was using natural gas as a kiln fuel and natural gas generally contains lower levels of sulfur containing compounds than coal. 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 Ideal. (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. (8) 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 diseases such as bronchitis may be aggravated by such exposures.

(25,26,27) NIOSH recommends a ceiling of 1 ppm to protect workers with pre-existing chronic bronchitis. ACGIH maintains a STEL (the limit not to be exceeded over a 15-minute period) of 5 ppm and a TWA of 3 ppm.

All of the 21 samples taken at Ideal Cement were below the recommended standard.

Toxic Gases

No sulfur dioxide or chlorine gas was detected. Carbon monoxide (1-2 ppm) and oxides of nitrogen (0.2-0.3 ppm) were detected around the natural gas heater/dryer near the primary crusher. 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 natural gas. When sulfur and nitrogen containing compounds are oxidized in the combustion process, sulfur dioxide and oxides of nitrogen gases are produced. Gasoline and diesel powered engines of locomotives, quarry equipment, transport trucks, and fork lifts 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.

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 Ideal Cement Plant in Okay, Arkansas are below recommended exposure levels. One sample from a conveyor operator exceeded the MSHA PEL for total nuisance particulate. Four respirable dust samples from workers associated with raw materials contained detectable levels of quartz. None of the dust containants measured are considered to be present in excessive concentrations.

Recommendations

Based on environmental measurements taken at Ideal Cement, Okay, Arkansas, on April 6-9, 1981, we conclude that the plant is providing a healthful work environment for its employees. No specific corrective actions are needed or recommended. Since the raw material mined at the plant contains crystalline silica (quartz), we do recommend surveillance monitoring on a periodic basis to assure that exposures remain within acceptable limits. The following discussion presents some guidance on available control strategies should they ever become necessary.

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. Workers are generally exposed to the highest dust concentrations during maintenance and clean-up operations. Since it is extremely difficult to design control systems to protect workers during these operations, workers may need to be provided with personal protective equipment.

During clean-up operations, workers often use compressed air to "blow down" the work areas. This process resuspends a great deal of dust. Substitution with a vacuum system would eliminate this problem.

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 represent good industrial hygiene practices, and 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 Jurnal, 30: 117, 1969.

10. Hosey, 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. Amdur, 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, Morgantown, WV; 1981.

22. NIOSH: Occupational Exposure to Oxides of Nitrogen, Criteria for a Recommended Standard; 1976.

23. Von Nieding, G., et al.; Protective Action of Atropine, Meclastine and Orciprenaline on Provocative Tests with NO_2 in Health Subjects and Patients with Chronic Non-specific Bronchitis; Ind. Arch. Arbeitsmed, 29:55-63; 1971.

24. Von Nieding, G., et al.; Studies of the Acute Effects of NO_2 on Lung Function, Influence on Diffusion, Perfusion, and Ventilation in the Lungs; Int. Arch. Arbeitsmed, 31:61-72; 1973.

25. Kosmider, S., et al.; Zentralbl. Arbeitsmed., 22:362; 1972.

26. Vigdortschik, N., et al.; J. Ind. Hyg and Toxi., 19:469; 1937.

Table 1

Environmental Investigations Branch

Industrial Hygiene Survey of Cement Workers
Ideal Cement, Okay, Arkansas

Number of Samples With Detectable Levels of Contaminants

Contaminant	# Samples Collected	# Samples with Detectable Conc.	Limit of Detection
Respirable dust	47	47	0.01 mg
Total dust	9	9	0.01 mg
Quartz	50	4	.005 mg
Cristobalite	50	0	0.03 mg
Aluminum	16	8	0.020 mg
Chromium	16	1	0.004 mg
Cobalt	16	0	0.005 mg
Magnesium	16	12	0.002 mg
Manganese	16	6	0.002 mg
Nickel	16	0	0.004 mg
Asbestos	13	0	4500 fibers
Sulfate	11	7	0.005 mg
Sulfite	11	6	0.010 mg
Sulfur dioxide	11	0	0.005 mg
Nitrogen dioxide	30	30	0.02 ppm

Table 2

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
IDEAL CEMENT OKAY, ARKANSAS
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
GROUPED BY EXPOSURE AREA

AREA=BACKGROUND

JOB	DATE	SHIFT	DUSTMGM3
BACKGROUND	08APR81	1	0.03

AREA=RAW

JOB	DATE	SHIFT	DUSTMGM3
FRONT END LOADER	06APR81	2	0.35
FRONT END LOADER	06APR81	2	0.28
SLURRY TANKMAN	06APR81	2	0.99
FRONT END LOADER	06APR81	2	0.11
MILLER (RAW)	06APR81	2	0.27
FRONT END LOADER	07APR81	1	0.20
MILLER (RAW)	08APR81	1	0.11
QUARRY TRUCK DRIVER	08APR81	1	0.12
FRONT END LOADER	08APR81	1	0.01
MECHANIC (QUARRY)	08APR81	1	0.45
FRONT END LOADER	08APR81	1	0.11
PRIMARY CRUSHER OPERATOR	08APR81	1	0.16
SLURRY TANKMAN	08APR81	1	0.04
QUARRY TRUCK DRIVER	09APR81	1	1.55
MILLER (RAW)	09APR81	1	0.24
MILLER (RAW)	09APR81	3	0.19

AREA=CLINKER

JOB	DATE	SHIFT	DUSTMGM3
KILN BURNER	06APR81	2	0.03
KILN OILER	06APR81	2	0.10
KILN OILER	07APR81	1	0.24
KILN BURNER	09APR81	1	0.08
KILN OILER	09APR81	1	0.28
COOLER OPERATOR	09APR81	1	0.57
KILN OILER	09APR81	3	0.20

AREA=FINISH

JOB	DATE	SHIFT	DUSTMGM3
MILL OPERATOR (FINISH)	06APR81	2	3.19
BULK LOADER	08APR81	1	0.04
MILL OPERATOR (FINISH)	08APR81	1	3.01
OILER (FINISH)	08APR81	1	0.13
PACKER TRUCKER	08APR81	1	0.74
BULK LOADER	08APR81	1	0.06
PACKER TRUCKER	09APR81	1	1.68
PACKER TRUCKER	09APR81	1	0.70

Table 2

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
IDEAL CEMENT OKAY, ARKANSAS
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
GROUPED BY EXPOSURE AREA

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

JOB	DATE	SHIFT	DUSTMGM3
TUNNELMAN (FINISH)	09APR81	1	0.57

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

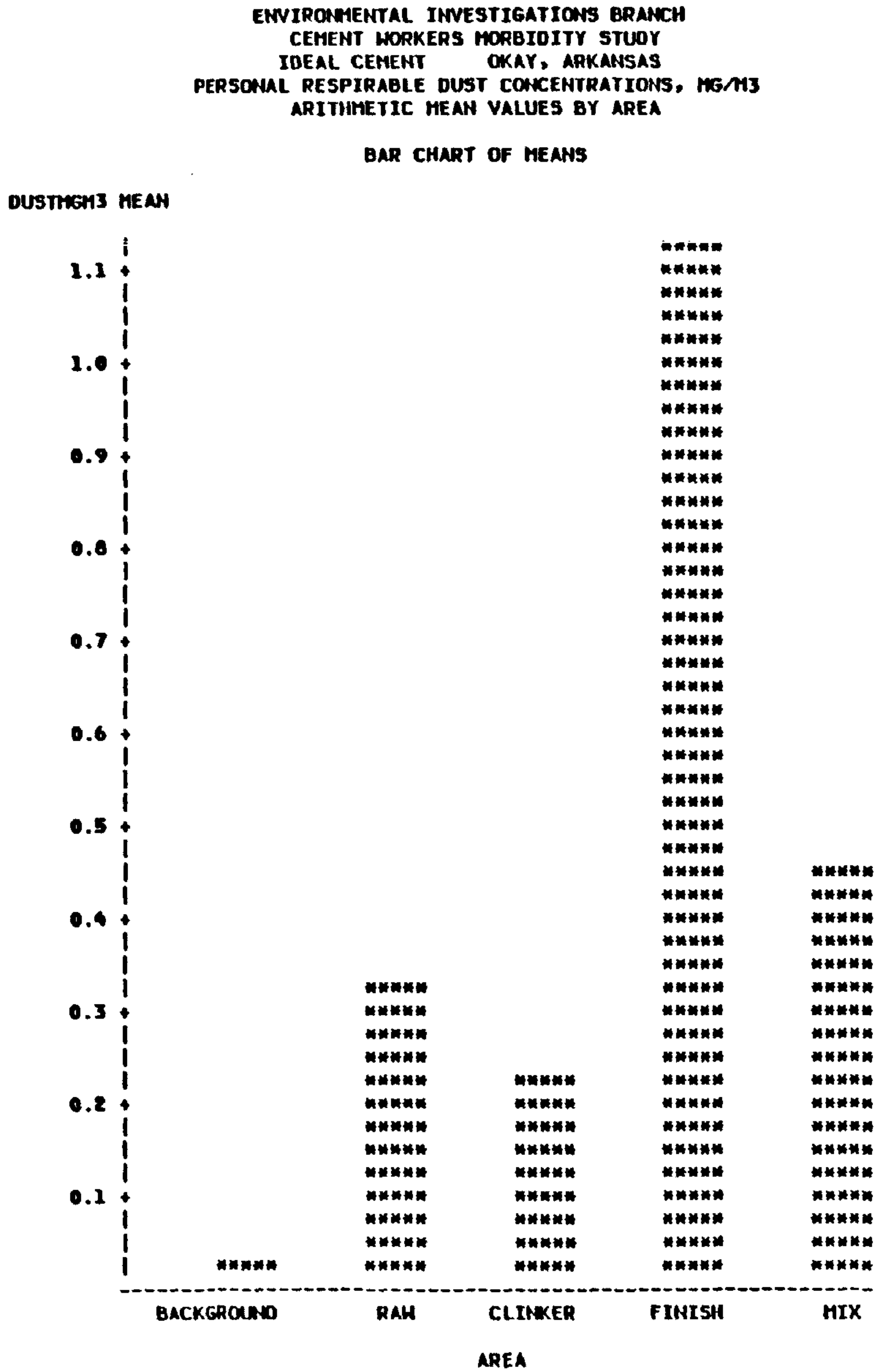
JOB	DATE	SHIFT	DUSTMGM3
CRANE OPERATOR	06APR81	2	0.23
REPAIRMAN	06APR81	2	0.21
LABORATORY WORKER	06APR81	2	0.67
WELDER	07APR81	1	2.16
MACHINIST	08APR81	1	0.20
REPAIRMAN	08APR81	1	0.34
YARD WORKERS	09APR81	1	0.72
YARD WORKERS	09APR81	1	0.09
ELECTRICIAN	09APR81	1	0.21
REPAIRMAN	09APR81	1	0.21
REPAIRMAN	09APR81	1	0.49
YARD WORKERS	09APR81	1	0.68
CRANE OPERATOR	09APR81	3	0.15
REPAIRMAN	09APR81	3	0.27
SHIFT FOREMAN (MIX)	09APR81	3	0.15

Table 3

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
IDEAL CEMENT OKAY, ARKANSAS
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3

AREA	SAMPLES	MEAN	STD	GM	GSD	NLOD	MIN	MAX
BACKGROUND	1	0.03	.	0.03	.	0	0.03	0.03
RAW	16	0.32	0.40	0.19	3.14	0	0.01	1.55
CLINKER	7	0.21	0.18	0.15	2.76	0	0.03	0.57
FINISH	9	1.12	1.23	0.48	5.12	0	0.04	3.19
MIX	15	0.45	0.52	0.31	2.27	0	0.09	2.16
PLANTWIDE	47	0.50	0.71	0.25	3.27	0	0.01	3.19

Figure 2



ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
IDEAL CEMENT OKAY, ARKANSAS
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
ARITHMETIC MEAN VALUES BY AREA
BAR CHART OF MEANS
DUSTMGM3 MEAN
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
BACKGROUND
RAW
CLINKER
FINISH
MIX
AREA

Figure 3

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
IDEAL CEMENT OKAY, ARKANSAS
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
ARITHMETIC MEAN VALUES BY JOB CATEGORY

BAR CHART OF MEANS

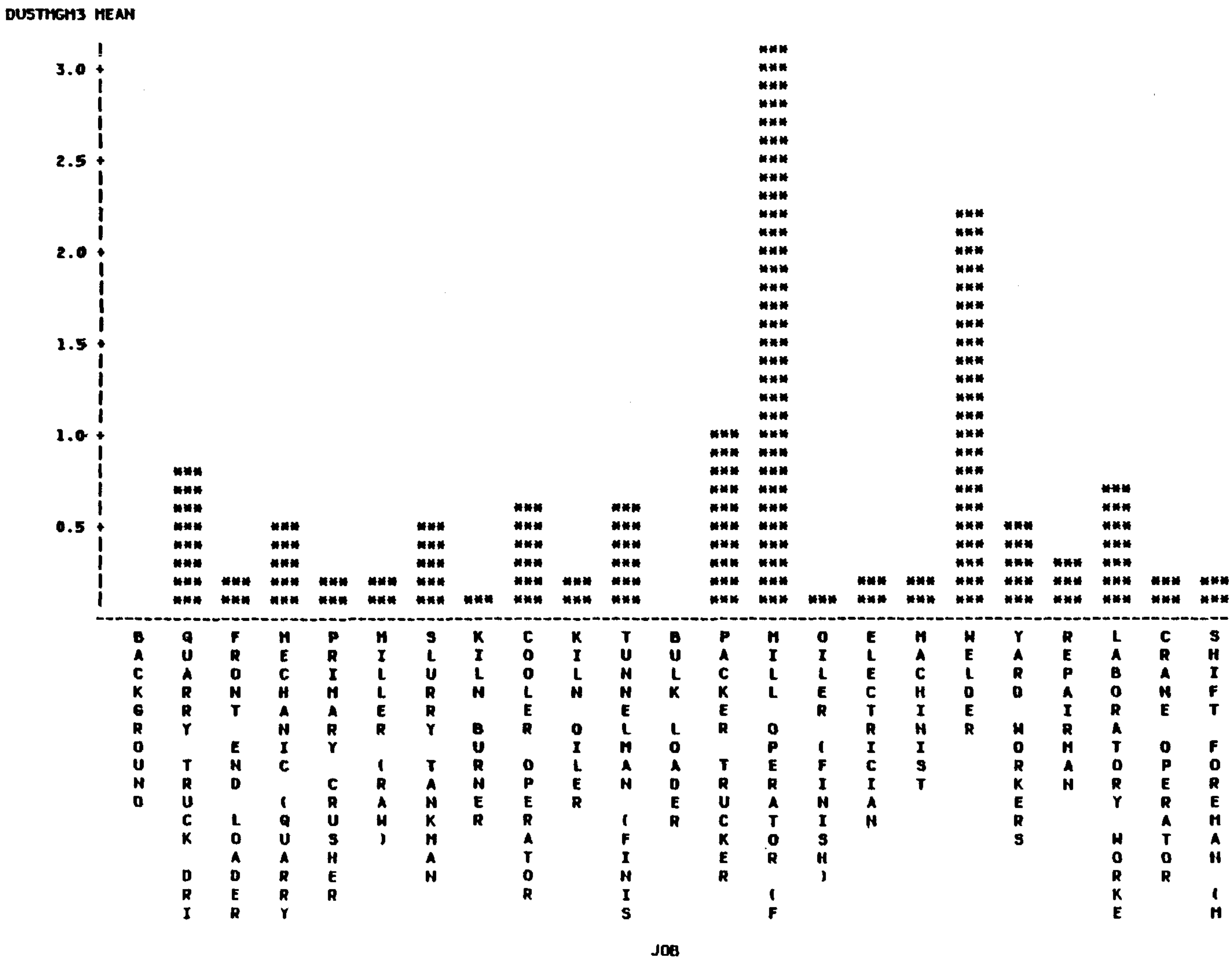


Table 4

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

JOB	DATE	SHIFT	PCT_SIO2	QUARTZ	AREA
MILLER (RAW)	06APR81	2	N	N	RAW
FRONT END LOADER	06APR81	2	N	N	RAW
~~SLURRY TANKMAN~~	~~06APR81~~	~~2~~	~~N~~	~~N~~	~~RAW~~
FRONT END LOADER	06APR81	2	N	N	RAW
FRONT END LOADER	06APR81	2	N	N	RAW
FRONT END LOADER	07APR81	1	N	N	RAW
QUARRY TRUCK DRIVER	07APR81	1	N	N	RAW
PRIMARY CRUSHER OPERATOR	07APR81	1	N	N	RAW
MECHANIC (QUARRY)	07APR81	1	N	N	RAW
CONVEYOR OPERATOR	07APR81	1	N	N	RAW
PRIMARY CRUSHER OPERATOR	08APR81	1	N	N	RAW
FRONT END LOADER	08APR81	1	N	N	RAW
MECHANIC (QUARRY)	08APR81	1	N	N	RAW
QUARRY TRUCK DRIVER	09APR81	1	N	N	RAW
MILLER (RAW)	09APR81	1	5.0	12.04	RAW
MILLER (RAW)	09APR81	3	N	N	RAW
SLURRY TANKMAN	09APR81	3	N	N	RAW
KILN OILER	07APR81	1	N	N	CLINKER
COOLER OPERATOR	07APR81	1	N	N	CLINKER
KILN BURNER	07APR81	1	N	N	CLINKER
KILN OILER	09APR81	3	N	N	CLINKER
COOLER OPERATOR	09APR81	1	N	N	CLINKER
KILN OILER	09APR81	1	5.0	14.24	CLINKER
KILN BURNER	09APR81	3	N	N	CLINKER
MILL OPERATOR (FINISH)	06APR81	2	N	N	FINISH
TUNNELMAN (FINISH)	07APR81	1	N	N	FINISH
BULK LOADER	08APR81	1	N	N	FINISH
MILL OPERATOR (FINISH)	08APR81	1	N	N	FINISH
TUNNELMAN (FINISH)	08APR81	1	N	N	FINISH
PACKER TRUCKER	09APR81	1	N	N	FINISH
MILL OPERATOR (FINISH)	09APR81	3	N	N	FINISH
BULK LOADER	09APR81	1	N	N	FINISH
CRANE OPERATOR	06APR81	2	N	N	MIX
REPAIRMAN	06APR81	2	N	N	MIX
LABORATORY WORKER	06APR81	2	N	N	MIX
WELDER	07APR81	1	N	N	MIX
PAINTER	07APR81	1	N	N	MIX
LABORATORY WORKER	07APR81	1	N	N	MIX
YARD WORKERS	07APR81	1	N	N	MIX
CRANE OPERATOR	07APR81	1	.	16.77	MIX
ELECTRICIAN	07APR81	1	.	108.11	MIX
REPAIRMAN	08APR81	1	N	N	MIX
STOREROOM SUPERINTENDENT	08APR81	1	N	N	MIX
YARD WORKERS	09APR81	1	N	N	MIX
REPAIRMAN	09APR81	3	N	N	MIX
REPAIRMAN	09APR81	1	N	N	MIX
YARD WORKERS	09APR81	1	N	N	MIX
ELECTRICIAN	09APR81	1	N	N	MIX
REPAIRMAN	09APR81	1	N	N	MIX
LABORATORY WORKER	09APR81	3	N	N	MIX

Table 5

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
IDEAL CEMENT OKAY, ARKANSAS
PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3
GROUPED BY EXPOSURE AREA

AREA=BACKGROUND

JOB	DATE	SHIFT	DUSTMGM3
BACKGROUND	08APR81	1	0.00

AREA=RAW

JOB	DATE	SHIFT	DUSTMGM3
QUARRY TRUCK DRIVER	08APR81	1	0.55
CONVEYOR OPERATOR	08APR81	1	21.12
FRONT END LOADER	08APR81	1	0.40

AREA=FINISH

JOB	DATE	SHIFT	DUSTMGM3
MILL OPERATOR (FINISH)	07APR81	1	3.31
SCALEMAN	07APR81	1	2.03
PACKER TRUCKER	07APR81	1	5.59
PACKER TRUCKER	08APR81	1	3.75

AREA=MIX

JOB	DATE	SHIFT	DUSTMGM3
YARD WORKERS	08APR81	1	2.62
WELDING SHOP	08APR81	1	6.09

Table 6

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
IDEAL CEMENT OKAY, ARKANSAS
PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3

AREA	SAMPLES	MEAN	STD	GM	GSD	NLOD	MIN	MAX
BACKGROUND	1	0.00	.	0.01	.	0	0.00	0.00
RAW	3	7.36	11.92	1.67	9.08	0	0.40	21.12
FINISH	4	3.67	1.48	3.44	1.52	0	2.03	5.59
MIX	1	2.62	.	2.62	.	0	2.62	2.62
MIX	1	6.09	.	6.09	.	0	6.09	6.09
PLANTWIDE	9	5.05	6.34	2.79	3.38	0	0.40	21.12

Figure 4

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
IDEAL CEMENT OKAY, ARKANSAS
PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3
ARITHMETIC MEAN VALUES BY AREA

BAR CHART OF MEANS

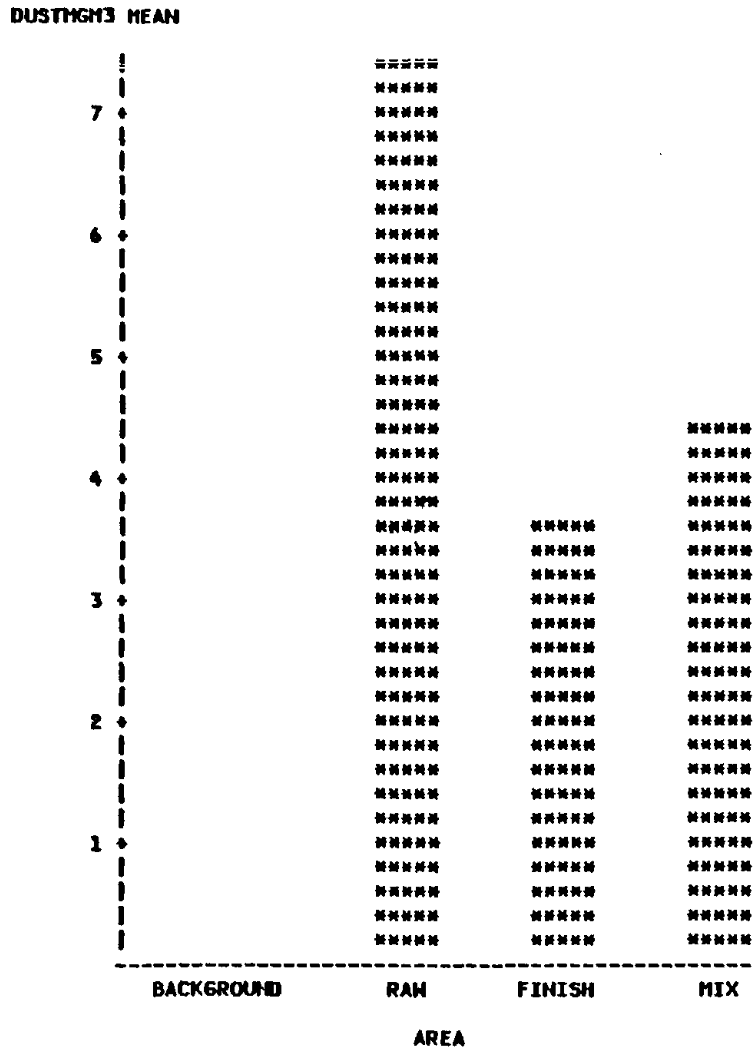


Figure 5

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
IDEAL CEMENT OKAY, ARKANSAS
PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3
ARITHMETIC MEAN VALUES BY JOB CATEGORY

BAR CHART OF MEANS

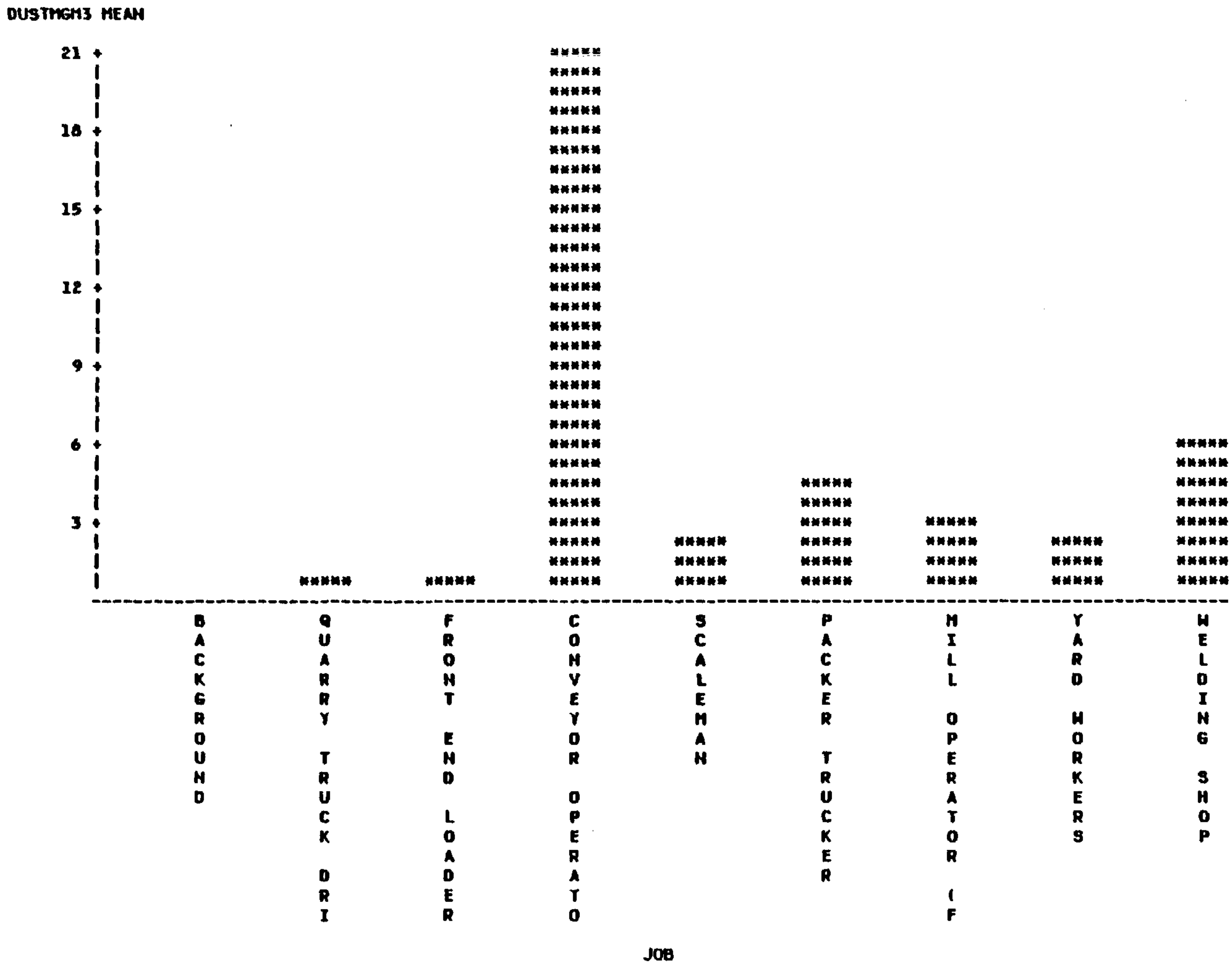


Table 7

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
IDEAL CEMENT OKAY, ARKANSAS
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	MN_UGM3	NI_UGM3
BACKGROUND	08APR81	1	BACKGROUND	N	N	N	N	N	N
RAW	06APR81	2	RAW MILLS	N	N	N	N	N	N
~~RAW~~	~~07APR81~~	~~1~~	~~PRIMARY CRUSHER~~	~~449~~	~~N~~	~~N~~	~~133~~	~~7~~	~~N~~
RAW	08APR81	1	PRIMARY CRUSHER	574	N	N	106	9	N
RAW	08APR81	1	RAW MILLS	N	N	N	2	N	N
CLINKER	06APR81	2	FRONT END OF KILN	N	N	N	N	N	N
CLINKER	08APR81	1	CLINKER CONVEYOR	2950	N	N	1391	71	N
CLINKER	08APR81	1	CLINKER COOLER	N	N	N	N	N	N
FINISH	07APR81	1	FINISH SILO TUNNEL	21	N	N	6	N	N
FINISH	07APR81	1	BAGGING	N	N	N	4	N	N
FINISH	08APR81	1	BULK LOADING SILOS	43	N	N	11	N	N
FINISH	08APR81	1	BULK LOADING SILOS	N	N	N	3	N	N
MIX	06APR81	2	OVERHEAD CRANE	N	N	N	N	N	N
MIX	06APR81	2	MILL ROOM	43	N	N	15	N	N
MIX	07APR81	1	OVERHEAD CRANE	1274	N	N	441	20	N
MIX	08APR81	1	WELDING SHOP	N	3	N	3	5	N
MIX	08APR81	1	OVERHEAD CRANE	154	N	N	55	2	N

Table 8

Environmental Investigations Branch

Industrial Hygiene Survey of Cement Workers
Ideal Cement, Okay, Arkansas

Trace Metal Concentrations from Area Total Dust Samples
In Micrograms Per Cubic Meter (ug/m^3)

Metal	N	Means	Std.dev.	Minimum	Maximum
Aluminum	8	689	1009	21	2958
Chromium	1	4	-	3	3
Mangesium	12	181	401	2	1392
Manganeese	6	19	26	2	71

Table 9

Environmental Investigations Branch
Industrial Hygiene Survey of Cement Workers
Ideal Cement, Okay, Arkansas

Trace Metals Concentrations as Measured by ICP-AES
Concentrations in Micrograms per Cubic Meter (ug/m^3)

	Exposure Categories			
Metals	Primary Crusher	Clinker Cooler	Mill Room	Packhouse
Aluminum	49.1	93.3	21.0	565.6
Calcium	1930.5	1861.5	620.2	12450.1
Chromium	N	N	N	2.4
Iron	45.2	54.7	14.1	284.0
Magnesium	21.1	27.2	8.2	151.9
Manganese	N	N	N	8.4
Sodium	12.0	N	N	43.2
Phosphorus	N	N	N	25.6
Titanium	N	N	N	22.7

The following elements were analyzed for, but were less than 1.0 ug/filter in all samples: silver, arsenic, beryllium, cadmium, cobalt, copper, lithium, molybdenum, nickel, lead, platinum, selenium, tin, tellrium, thallium, vanadium, yttrium, zinc, and zirconium.

Table 10

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
IDEAL CEMENT OKAY, ARKANSAS
ANALYSIS OF BULK MATERIAL PRESENTED AS PERCENT BY WEIGHT

AREA	JOB	QUARTZ	CRISTB	AL	CR	CO	MG	MN	NI	ASBEST
RAW	RAW MATERIAL	N	N	1.49	N	N	0.45	0.02	N	0.0
RAW	RAW MATERIAL	N	N	0.82	N	N	0.32	0.02	N	0.0
RAW	RAW MATERIAL	N	N	1.48	N	N	0.42	0.02	N	0.0
RAW	RAW MATERIAL	1.7	N	1.18	N	0.01	0.40	0.02	N	0.0
RAW	RAW MATERIAL	N	N	1.50	N	N	0.41	0.02	N	0.0
RAW	RAW MATERIAL	N	N	1.44	N	N	0.46	0.02	0.04	0.0
CLINKER	CLINKER	N	N	3.20	N	N	0.69	0.04	0.05	0.0
CLINKER	CLINKER	N	N	3.62	N	0.01	0.75	0.03	N	0.0
CLINKER	CLINKER	N	N	2.02	N	0.01	0.59	0.03	0.03	0.0
CLINKER	CLINKER	N	N	2.17	N	0.01	0.62	0.03	N	0.0
CLINKER	CLINKER	N	N	2.66	N	N	0.68	0.03	N	0.0
CLINKER	CLINKER	N	N	2.45	N	0.01	0.65	0.03	0.02	0.0
CLINKER	CLINKER	.	.	2.84	N	N	0.71	0.03	0.02	.
FINISH	FINISH	N	N	2.98	N	0.01	0.60	0.03	0.02	0.0
FINISH	FINISH	N	N	2.70	N	N	0.63	0.03	N	0.0
FINISH	FINISH	N	N	1.56	N	N	0.42	0.03	N	0.0
FINISH	FINISH	N	N	2.67	N	N	0.61	0.03	0.03	0.0
FINISH	FINISH	N	N	2.59	N	N	0.60	0.03	N	0.0
FINISH	FINISH	N	N	2.85	N	N	0.66	0.03	N	0.0
MIX	RAW CLINKER	8.4	N	1.90	N	N	0.19	N	N	0.0

Table 11

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
IDEAL CEMENT OKAY, ARKANSAS
SOX CONCENTRATIONS

JOB	DATE	SHIFT	AREA	SO4_UGM3	SO3_UGM3	SO2_PPM
BACK END OF KILN	06APR81	2	RAW	N	N	N
PRECIPITATOR OF KILN (WASTE DUST)	06APR81	2	RAW	N	N	N
RAW MILLS	07APR81	1	RAW	11.47	N	N
PRIMARY CRUSHER	08APR81	1	RAW	54.72	N	N
DISCHARGE STACK (BOTTOM)	08APR81	1	RAW	8.93	N	N
FRONT END OF KILN	06APR81	2	CLINKER	11.97	N	0.01
FRONT END OF KILN	08APR81	1	CLINKER	N	N	N
CLINKER COOLER	08APR81	1	CLINKER	N	N	0.01
FRONT END OF KILN	08APR81	1	CLINKER	11.28	N	N
BAGGING	07APR81	1	FINISH	130.61	N	N
OVERHEAD CRANE	07APR81	1	MIX	134.79	N	N

Table 12

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
IDEAL CEMENT OKAY, ARKANSAS
NO2 CONCENTRATIONS IN PPM

JOB	DATE	SHIFT	AREA	CONC
QUARRY TRUCK DRIVER	08APR81	1	RAW	0.16
FRONT END LOADER	08APR81	1	RAW	0.05
MECHANIC (QUARRY)	08APR81	1	RAW	0.06
FRONT END LOADER	08APR81	1	RAW	0.07
PRIMARY CRUSHER OPERATOR	08APR81	1	RAW	0.12
SLURRY TANKMAN	08APR81	1	RAW	0.44
MILLER (RAW)	08APR81	1	RAW	0.04
MILLER (RAW)	09APR81	1	RAW	0.08
QUARRY TRUCK DRIVER	09APR81	1	RAW	0.18
KILN BURNER	09APR81	1	CLINKER	0.04
KILN OILER	09APR81	1	CLINKER	0.07
COOLER OPERATOR	09APR81	1	CLINKER	0.05
TUNNELMAN (FINISH)	08APR81	1	FINISH	0.08
PACKER TRUCKER	08APR81	1	FINISH	0.06
BULK LOADER	08APR81	1	FINISH	0.12
BULK LOADER	08APR81	1	FINISH	0.06
MILL OPERATOR (FINISH)	08APR81	1	FINISH	0.05
OILER (FINISH)	08APR81	1	FINISH	0.06
PACKER TRUCKER	09APR81	1	FINISH	0.04
PACKER TRUCKER	09APR81	1	FINISH	0.14
BULK LOADER	09APR81	1	FINISH	0.10
TUNNELMAN (FINISH)	09APR81	1	FINISH	0.08
MACHINIST	08APR81	1	MIX	0.06
STOREROOM SUPERINTENDENT	08APR81	1	MIX	0.07
REPAIRMAN	08APR81	1	MIX	0.06
REPAIRMAN	09APR81	1	MIX	0.06
REPAIRMAN	09APR81	1	MIX	0.14
YARD WORKERS	09APR81	1	MIX	0.08
YARD WORKERS	09APR81	1	MIX	0.07
ELECTRICIAN	09APR81	1	MIX	0.06

Table 13

Environmental Investigations Branch

Cement Workers Morbidity Study
Ideal Cement, Okay, Arkansas

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

Date	Area	SO_2	CO	NO_x	Cl2
April 7	Natural Gas heater/dryer for 1° crusher		1-2	0.2-0.2	
	Fire end of Kiln		0	0	
	Clinker cooler		0		
April 8	Base of kiln discharge stacks	0			
	Between kilns	0			
	Mill Room		0		
	Cooler drag chain		0		
	Chlorine tanks for water treatment				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.