Industrial Hygiene Survey of Flintkote Cement Co.

San Andreas, California

Cement Workers Morbidity Study

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Executive Summary

The Flintkote Cement Plant in San Andreas, California was surveyed by a NIOSH team of industrial hygienists, on March 9 through March 12, 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 ACGIH recommended exposure levels of 5 mg/m^3 for respirable dust and 10 mg/m^3 for total dust. Six personal respirable dust samples and five personal total dust samples exceeded these levels. The jobs of highest exposure were laborers, packers, repairmen, electricians, oilers, kiln feed operators, and finish mill operators. Of the dust contaminants measured, only quartz is present in excessive concentrations. Exposure to quartz was observed in the raw mill, finish mill, packhouse, coal shed, and the quarry.

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. Flintkote Cement in San Andreas, California was the sixth 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 Flintkote Cement plant in San Andreas, California was surveyed on Monday, March 9 through Thursday, March 12, 1981, by Cathy Davidson, Thomas Wood, and Wayne Sanderson. The Flintkote Cement plant is located three miles south of San Andreas. Cement clinkers are produced in three kilns by the wet process method. These kilns have been in operation since 1945 and are presently fueled by pulverized coal. Limestone, from a quarry over 17 miles away, serves as the calcium source. The limestone is crushed and milled into a slurry at the quarry site, and then pumped through a pipeline to the plant site where it is blended with other raw materials. Other raw materials include:

clay - aluminum source
sand - silica source
iron ore - iron source

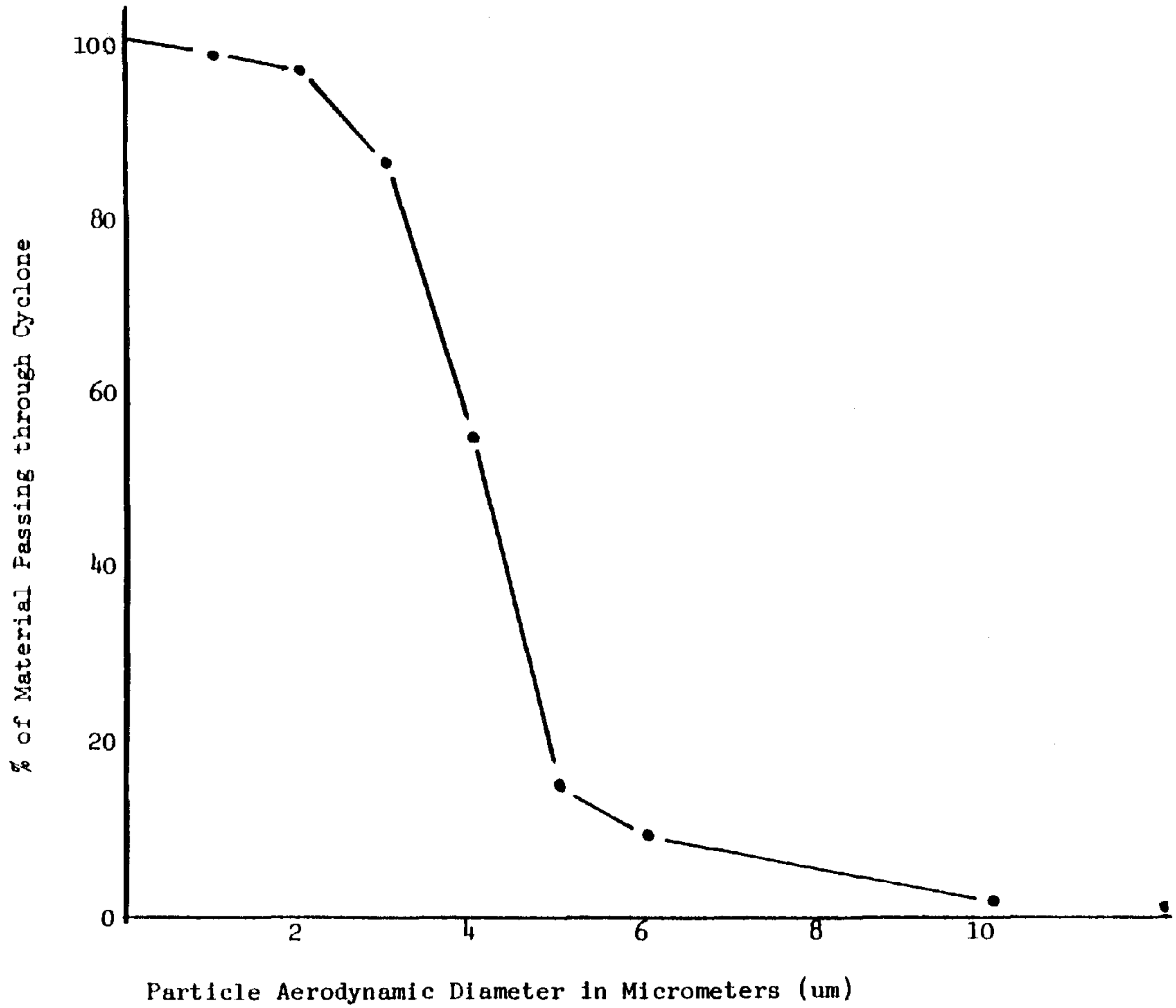
The six types of finished cement which are produced at this plant, are bagged or loaded as bulk in trucks or railcars.

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 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 washed 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 30 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 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 12 samples were collected for fibers. These samples were collected in the raw material crushing and milling areas, storage areas, kiln and clinker cooler 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 which exposure category the samples were taken. The JOB column lists whether the material was felt to be predominantly raw material, clinker, finished cement, a mixture of dusts, or other materials such as insulation. 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. Six samples were collected for sulfate and sulfite particulates and sulfur dioxide gas. Four samples indicated sulfate particulate levels between 11.13 to 1750.1 ug/m^3 These results are presented in Table 14. No sulfur dioxide gas or sulfite particulates were detected on any of the samples.

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 within specifications, sampler adjustments and appropriate notations were made and, if necessary, the results of such samples were voided.

The environmental investigations team began sampling Monday, March 9, 1981. The sampling schedule was as follows:

Monday, March 9 - 2nd shift

Tuesday, March 10 - 1st shift

Wednesday, March 11 - 1st shift

Thursday, March 12 - 1st shift

Thursday, March 12 - 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:

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

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 the various jobs, Table 2, six samples exceeded 5.0 mg/m^3. These samplers were worn by a kiln feed operator, an oiler in the finish mill, a finish mill operator, an electrician at the quarry, and two repairmen. Both repairmen were welding during the shift, and the concentrations reported could be from heavy metal fume rather than airborne dust particles. For all workers, the geometric mean respirble dust level was 0.90 mg/m^3.

Of the personal total samples, four exceeded 10.0 mg/m^3. These samples were worn by a packer, a yard laborer, and two repairmen. The yard laborer had the highest exposure level measured. On the day sampled, he was using a bobcat to clean under the screens and elevator basements in the finish mill room. Both repairmen were welding which could cause a higher weight to be measured as explained above. For all workers, the geometric mean total dust level was 4.01 mg/m^3.

Because of the differences in worker duties and activities, some jobs consistently encounter higher or lower dust levels than other jobs. However, within a given job category, variability is often slight. Figures 3 and 5 chart the means of the respirable and total dust measurements respectively, for each job. Repairmen, laborers, kiln feed operators, packhouse workers, mill helpers, kiln oilers, and electricians 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 three bulk samples: waste precipitator dust, clinker dust, and plastic cement. Quartz is a common constituent of limestone, shale, clay, and sand, but is rarely found in clinker. As silicon dioxide passes through the high kiln temperatures, it is transformed from free crystalline forms into silicates. Quartz is commonly found in waste precipitator dust, but not clinker or finished cement. However, a quartz containing compound may be added during the grinding process of plastic cement production.

Eleven of seventy-two personal respirable samples contained detectable levels of quartz. Quartz was found in samples from the following jobs: kiln feed operators, slurry tankman, kiln burner, finish mill helper, packhouse loader operator, electricians, coal handler, and machinist. The kiln feed operators and slurry tankman loaded trucks with precipitator dust. The finish mill helper and kiln burner were exposed to clinker dust and coal dust. The packhouse loader operator was exposed to plastic cement. The duties of electricians and machinists carry them into many areas of the plant. The coal handler, whose sample contained the highest percentage of quartz, was exposed only to coal dust. Although we did not collect a bulk coal sample, quartz is a common contaminant of coal. Since the coal was milled near the cooler where the quartz-containing clinker sample was collected, coal may have contaminated this bulk clinker sample.

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 0.9 - 68.7%.

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. Eight of the eleven samples exceed the permissible exposure limit. Five of the eleven samples with detectable levels of quartz, contained concentrations greater than 100 ug/m^3. Exposures below this level have been suggested in past research as safe levels of exposure. (9,10,11) The kiln feed operators, coal handlers, and machinist were exposed to the highest quartz levels.

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 five 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, sodium, and potassium.

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

Sulfate particulates were detected on four of the six samples taken. These samples were taken from the bottom of the kiln discharge stack, at the precipitator of the kiln, the clinker cooler, and the front end of the kiln. No sulfite particulates or sulfur dioxide was detected. 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 Flintkote. (1, 12, 13)

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 6 list the background respirable and total dust levels, respectively.

Conclusion

The respirable and total dust levels for most jobs at the Flintkote Cement plant in San Andreas, California are below recommended exposure levels. Six respirable and four total dust samples exceeded the ACGIH recommended levels for nuisance particulate. Eleven respirable dust samples contained detectable levels of quartz. Eight 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

Workers should be monitored further for respirable quartz concentrations. Monitoring will help to determine those jobs with highest quartz exposure. Jobs of greatest concern are the kiln feed operators and coal handlers.

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.

The kiln feed operators are overexposed to quartz while loading haulage trucks with waste precipitator dust. If they loaded these trucks from an enclosed control room, they would be shielded from dust exposure. Finish mill workers are overexposed to nuisance particulate. Airborne dust is generated in this area as material is transferred through the mill systems. Improvements and repairs in the duct-work and elevators through which the material is moved would reduce the amount of fugitive dusts escaping into the workroom air. To protect maintenance workers and laborers, engineering controls may not be applicable. Then you may resort to personal protective devices.

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. 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).

Table 1

Environmental Investigations Branch

Industrial Hygiene Survey of Cement Workers

Flintkote Cement, San Andreas, California

Number of Samples With Detectable Levels of Contaminants

Contaminant	# Samples Collected	# Samples with Detectable Conc.	Limit of Detection
Respirable dust	77	74	0.01 mg
Total dust	20	19	0.01 mg
Quartz	73	11	0.03 mg
Cristobalite	73	0	0.03 mg
Aluminum	38	28	0.20 mg
Chromium	38	7	0.004 mg
Cobalt	38	2	0.005 mg
Magnesium	38	38	0.002 mg
Manganese	38	15	0.002 mg
Nickel	38	4	0.004 mg
Asbestos	12	0	4500 fibers
Sulfate	6	4	0.005 mg
Sulfite	6	0	0.01 mg
Sulfur dioxide	6	0	0.005 mg

Table 2

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT SAN ANDREAS, CALIFORNIA
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
GROUPED BY EXPOSURE AREA

AREA=BACKGROUND

JOB	DATE	SHIFT	DUSTMGM3
BACKGROUND	09MAR81	2	0.03
BACKGROUND	11MAR81	1	0.08
BACKGROUND	12MAR81	1	0.00
BACKGROUND	12MAR81	3	0.00

AREA=RAW

JOB	DATE	SHIFT	DUSTMGM3
KILN FEED OPERATOR	09MAR81	2	2.65
KILN FEED OPERATOR	10MAR81	1	2.18
LABORER (QUARRY)	11MAR81	1	2.39
FRONT END LOADER	11MAR81	1	0.22
FRONT END LOADER	11MAR81	1	0.58
PRIMARY CRUSHER OPERATOR	11MAR81	1	0.79
DRILLER	11MAR81	1	4.94
QUARRY TRUCK DRIVER	11MAR81	1	1.64
MILL HELPER (RAW)	11MAR81	1	0.10
KILN FEED OPERATOR	12MAR81	1	7.70
MILLER (RAW)	12MAR81	3	0.27
SLURRY TANKMAN	12MAR81	3	0.78

AREA=CLINKER

JOB	DATE	SHIFT	DUSTMGM3
KILN BURNER	09MAR81	2	0.14
KILN BURNER	10MAR81	1	0.54
CRANE OPER (CLINKER)	10MAR81	1	3.72
CRANE OPER (CLINKER)	12MAR81	1	1.39
KILN BURNER	12MAR81	1	1.19
KILN BURNER	12MAR81	3	0.53

AREA=FINISH

JOB	DATE	SHIFT	DUSTMGM3
MILL OPERATOR (FINISH)	09MAR81	2	3.10
FINISH MILL HELPER	09MAR81	2	3.49
BULK LOADER	09MAR81	2	0.69
BULK LOADER	09MAR81	2	0.44
TUNNELMAN (FINISH)	09MAR81	2	1.47
TUNNELMAN (FINISH)	09MAR81	2	1.59
TUNNELMAN (FINISH)	10MAR81	1	2.00
OILER (FINISH)	10MAR81	1	5.71
MILL OPERATOR (FINISH)	10MAR81	1	3.86
PACKER	10MAR81	1	2.62

Table 2

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT   SAN ANDREAS, CALIFORNIA
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
GROUPED BY EXPOSURE AREA

AREA=FINISH

JOB	DATE	SHIFT	DUSTMGM3
BULK LOADER	10MAR81	1	0.49
TUNNELMAN (FINISH)	12MAR81	1	2.44
PACKHOUSE FOREMAN	12MAR81	1	0.38
LOADER OPERATOR	12MAR81	1	0.40
PALLETIZER OPER	12MAR81	1	4.61
BULK LOADER	12MAR81	1	0.36
PACKER	12MAR81	1	2.09
TUNNELMAN (FINISH)	12MAR81	1	1.99
FINISH MILL HELPER	12MAR81	1	2.64
MILL OPERATOR (FINISH)	12MAR81	3	11.92
TUNNELMAN (FINISH)	12MAR81	3	0.72
BULK LOADER	12MAR81	3	0.58
TUNNELMAN (FINISH)	12MAR81	3	1.10
FINISH MILL HELPER	12MAR81	3	2.43

AREA=MIX

JOB	DATE	SHIFT	DUSTMGM3
ELECTRICIAN	09MAR81	2	0.74
REPAIRMAN	09MAR81	2	7.87
REPAIRMAN	09MAR81	2	5.96
REPAIRMAN	09MAR81	2	1.45
SHIFT FOREMAN	09MAR81	2	0.53
MOBILE EQUIPMENT OPER (PLANT)	09MAR81	2	0.68
LABORER	09MAR81	2	3.11
MACHINIST	10MAR81	1	0.19
YARD WORKERS	10MAR81	1	1.79
YARD WORKERS	10MAR81	1	0.45
COKE COAL HANDLER	10MAR81	1	0.18
OILER (GENERAL)	10MAR81	1	0.17
YARD WORKERS	10MAR81	1	0.44
REPAIRMAN	10MAR81	1	0.52
STOREROOM SUPERINTENDENT	11MAR81	1	0.09
SWEEPER DRIVER	11MAR81	1	0.39
ELECTRICIAN	11MAR81	1	6.52
LABORER	12MAR81	1	2.24
COKE COAL HANDLER	12MAR81	1	0.23
MACHINIST	12MAR81	1	0.11
STOREROOM SUPERINTENDENT	12MAR81	1	0.36
LABORER	12MAR81	1	4.44
PAINTER	12MAR81	1	0.50
LABORATORY WORKER	12MAR81	1	0.22
ELECTRICIAN	12MAR81	1	1.51
MOBILE EQUIPMENT OPER (PLANT)	12MAR81	3	1.39
MACHINIST	12MAR81	3	0.00
MACHINIST	12MAR81	3	2.03
ELECTRICIAN	12MAR81	3	0.78
LABORER	12MAR81	3	0.57

Table 2

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT   SAN ANDREAS, CALIFORNIA
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
GROUPED BY EXPOSURE AREA

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

JOB	DATE	SHIFT	DUSTMGM3
LABORATORY WORKER	12MAR81	3	0.00

Table 3

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT SAN ANDREAS, CALIFORNIA
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3

AREA	SAMPLES	MEAN	STD	GM	GSD	NLOD	MIN	MAX
BACKGROUND	4	0.03	0.04	0.02	2.73	0	0.00	0.08
RAW	12	2.02	2.27	1.05	3.72	0	0.10	7.70
CLINKER	6	1.25	1.30	0.79	3.04	0	0.14	3.72
FINISH	24	2.38	2.49	1.55	2.62	0	0.36	11.92
MIX	31	1.47	2.04	0.57	5.01	0	0.00	7.87
PLANTWIDE	73	1.84	2.19	0.90	4.00	0	0.00	11.92

Figure 2

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT   SAN ANDREAS, CALIFORNIA
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
ARITHMETIC MEAN VALUES BY AREA

BAR CHART OF MEANS

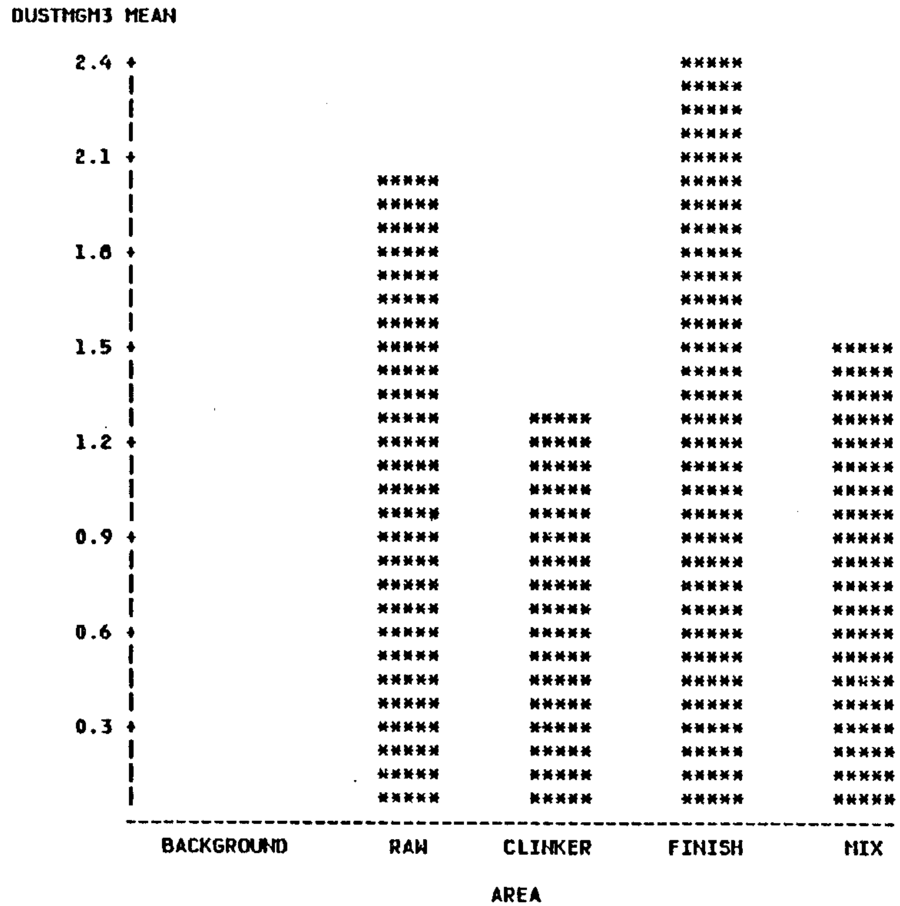


Figure 3

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT SAN ANDREAS, CALIFORNIA
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
ARITHMETIC MEAN VALUES BY JOB CATEGORY

BAR CHART OF MEANS

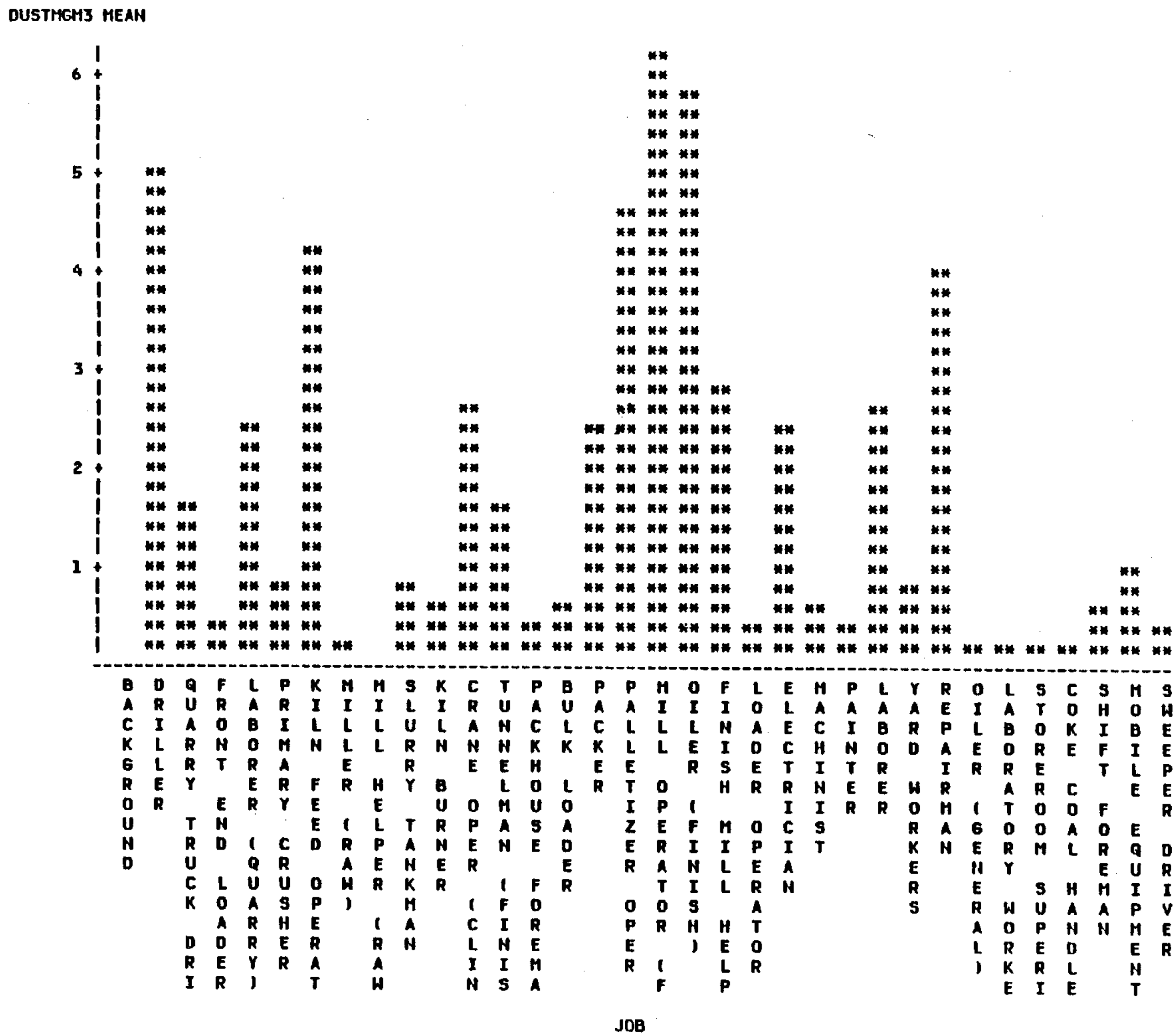


Table 4

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT SAN ANDREAS, CALIFORNIA
QUARTZ CONCENTRATION OF PERSONAL RESPIRABLE DUST SAMPLES
QUARTZ CONCENTRATION IN MICROGRAMS PER CUBIC METER (UG/M3)

JOB	DATE	SHIFT	PCT_SIO2	QUARTZ	AREA
BACKGROUND	12MAR81	3	N	N	BACKGROUND
KILN FEED OPERATOR	09MAR81	2	5.2	138.21	RAW
KILN FEED OPERATOR	10MAR81	1	6.0	130.79	RAW
QUARRY TRUCK DRIVER	11MAR81	1	N	N	RAW
DRILLER	11MAR81	1	N	N	RAW
PRIMARY CRUSHER OPERATOR	11MAR81	1	N	N	RAW
LABORER (QUARRY)	11MAR81	1	N	N	RAW
FRONT END LOADER	11MAR81	1	N	N	RAW
FRONT END LOADER	11MAR81	1	N	N	RAW
MILL HELPER (RAW)	11MAR81	1	N	N	RAW
FRONT END LOADER	11MAR81	1	N	N	RAW
KILN FEED OPERATOR	12MAR81	1	2.3	173.91	RAW
SLURRY TANKMAN	12MAR81	3	7.0	54.20	RAW
KILN BURNER	09MAR81	2	N	N	CLINKER
KILN BURNER	10MAR81	1	N	N	CLINKER
CRANE OPER (CLINKER)	10MAR81	1	N	N	CLINKER
KILN BURNER	12MAR81	1	6.1	72.32	CLINKER
CRANE OPER (CLINKER)	12MAR81	1	N	N	CLINKER
KILN BURNER	12MAR81	3	N	N	CLINKER
TUNNELMAN (FINISH)	09MAR81	2	N	N	FINISH
PACKHOUSE FOREMAN	09MAR81	2	N	N	FINISH
BULK LOADER	09MAR81	2	N	N	FINISH
FINISH MILL HELPER	09MAR81	2	1.6	55.82	FINISH
BULK LOADER	09MAR81	2	N	N	FINISH
TUNNELMAN (FINISH)	09MAR81	2	N	N	FINISH
PACKER	10MAR81	1	N	N	FINISH
BULK LOADER	10MAR81	1	N	N	FINISH
MILL OPERATOR (FINISH)	10MAR81	1	N	N	FINISH
OILER (FINISH)	10MAR81	1	N	N	FINISH
TUNNELMAN (FINISH)	10MAR81	1	N	N	FINISH
TUNNELMAN (FINISH)	12MAR81	3	N	N	FINISH
PACKER	12MAR81	1	N	N	FINISH
PALLETIZER OPER	12MAR81	1	N	N	FINISH
MILL OPERATOR (FINISH)	12MAR81	3	N	N	FINISH
PACKHOUSE FOREMAN	12MAR81	1	N	N	FINISH
LOADER OPERATOR	12MAR81	1	10.7	42.36	FINISH
TUNNELMAN (FINISH)	12MAR81	3	N	N	FINISH
FINISH MILL HELPER	12MAR81	3	N	N	FINISH
BULK LOADER	12MAR81	1	N	N	FINISH
FINISH MILL HELPER	12MAR81	1	N	N	FINISH
TUNNELMAN (FINISH)	12MAR81	1	N	N	FINISH
TUNNELMAN (FINISH)	12MAR81	1	N	N	FINISH
BULK LOADER	12MAR81	3	N	N	FINISH
ELECTRICIAN	09MAR81	2	N	N	MIX
SHIFT FOREMAN	09MAR81	2	N	N	MIX
REPAIRMAN	09MAR81	2	N	N	MIX
REPAIRMAN	09MAR81	2	N	N	MIX
REPAIRMAN	09MAR81	2	N	N	MIX
LABORER	09MAR81	2	N	N	MIX
OFFICE WORKER	10MAR81	1	N	N	MIX
MACHINIST	10MAR81	1	N	N	MIX
YARD WORKERS	10MAR81	1	N	N	MIX

Table 4

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT   SAN ANDREAS, CALIFORNIA
QUARTZ CONCENTRATION OF PERSONAL RESPIRABLE DUST SAMPLES
QUARTZ CONCENTRATION IN MICROGRAMS PER CUBIC METER (UG/M3)

JOB	DATE	SHIFT	PCT_SIO2	QUARTZ	AREA
YARD WORKERS	10MAR81	1	N	N	MIX
COKE COAL HANDLER	10MAR81	1	N	N	MIX
YARD WORKERS	10MAR81	1	N	N	MIX
REPAIRMAN	10MAR81	1	N	N	MIX
SWEEPER DRIVER	11MAR81	1	N	N	MIX
ELECTRICIAN	11MAR81	1	0.9	58.76	MIX
STOREROOM SUPERINTENDENT	11MAR81	1	N	N	MIX
STOREROOM SUPERINTENDENT	12MAR81	1	N	N	MIX
MACHINIST	12MAR81	3	N	N	MIX
COKE COAL HANDLER	12MAR81	1	68.7	155.01	MIX
LABORER	12MAR81	3	N	N	MIX
PAINTER	12MAR81	1	N	N	MIX
ELECTRICIAN	12MAR81	1	6.0	90.45	MIX
MACHINIST	12MAR81	3	7.1	145.13	MIX
LABORER	12MAR81	1	N	N	MIX
LABORATORY WORKER	12MAR81	1	N	N	MIX
LABORATORY WORKER	12MAR81	3	N	N	MIX
MOBILE EQUIPMENT OPER (PLANT)	12MAR81	3	N	N	MIX
ELECTRICIAN	12MAR81	3	N	N	MIX
LABORER	12MAR81	1	N	N	MIX
MACHINIST	12MAR81	1	N	N	MIX

Table 5

Environmental Investigations Branch

Industrial Hygiene Survey of Cement Workers
Flintkote Cement, San Andreas, California

Detectable Quartz Compared to MSHA Permissible Exposure Levels

Job	Levels of Dust Conc. Mg/m^3	Quartz Conc. % Quartz	Quartz Conc. ug/m^3	MSHA PEL Mg/m^3
Kiln Feed Op.	2.65*	5.2	138.21	1.39
Kiln Feed Op.	2.18*	6.0	130.79	1.24
Kiln Feed Op.	7.70*	2.3	173.91	1.89
Slurry Tankman	0.78	7.0	54.20	1.11
Kiln burner	1.19	6.1	72.32	1.23
Finish mill help.	3.49 *	1.6	55.82	2.78
Loader operator	0.40	10.7	42.36	0.79
Electrician	6.52 *	0.9	58.76	3.45
Coal handler	0.23 *	68.7	155.01	0.14
Electrician	1.51 *	6.0	90.45	1.25
Machinist	2.03 *	7.0	145.13	1.11

*Indicates measured concentration exceeds the MSHA Permissible Exposure Limit.

Table 6

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT SAN ANDREAS, CALIFORNIA
PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3
GROUPED BY EXPOSURE AREA

AREA=BACKGROUND

JOB	DATE	SHIFT	DUSTMGM3
BACKGROUND	09MAR81	2	0.13
BACKGROUND	10MAR81	1	0.02
BACKGROUND	11MAR81	1	0.00

AREA=RAW

JOB	DATE	SHIFT	DUSTMGM3
FRONT END LOADER	11MAR81	1	2.03
QUARRY TRUCK DRIVER	11MAR81	1	1.70

AREA=FINISH

JOB	DATE	SHIFT	DUSTMGM3
MILL OPERATOR (FINISH)	12MAR81	1	9.04
PACKER	12MAR81	1	21.07
TUNNELMAN (FINISH)	12MAR81	1	9.71

AREA=MIX

JOB	DATE	SHIFT	DUSTMGM3
REPAIRMAN	09MAR81	2	26.19
LABORATORY WORKER	09MAR81	2	3.97
STOREROOM SUPERINTENDENT	09MAR81	2	1.43
MACHINIST	09MAR81	2	0.76
ELECTRICIAN	10MAR81	1	2.53
REPAIRMAN	10MAR81	1	33.86
OILER (GENERAL)	10MAR81	1	5.09
JANITOR	12MAR81	1	0.50
PAINTER	12MAR81	1	3.41
LABORER	12MAR81	1	35.23
LABORATORY WORKER	12MAR81	1	0.59
COKE COAL HANDLER	12MAR81	1	1.57

Table 7

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT SAN ANDREAS, CALIFORNIA
PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3

AREA	SAMPLES	MEAN	STD	GM	GSD	NLOD	MIN	MAX
BACKGROUND	3	0.05	0.07	0.03	3.95	0	0.00	0.13
RAW	2	1.87	0.24	1.86	1.14	0	1.70	2.03
FINISH	3	13.28	6.76	12.28	1.60	0	9.04	21.07
MIX	12	9.59	13.60	3.44	4.58	0	0.50	35.23
PLANTWIDE	17	9.33	11.95	4.01	4.04	0	0.50	35.23

Figure 4

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT SAN ANDREAS, CALIFORNIA
PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3
ARITHMETIC MEAN VALUES BY AREA

BAR CHART OF MEANS

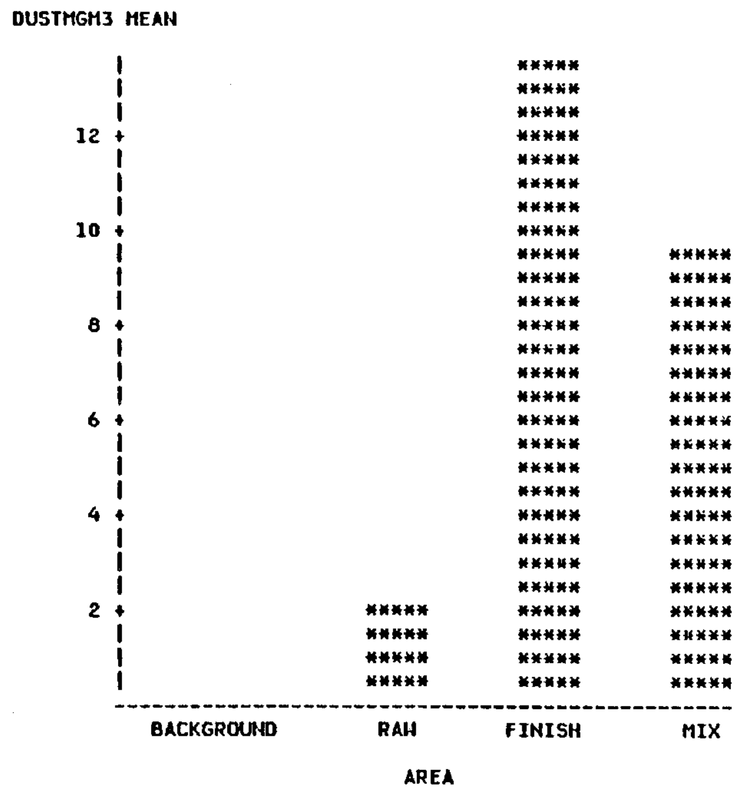


Figure 5

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT SAN ANDREAS, CALIFORNIA
PERSONAL TOTAL DUST CONCENTRATIONS, MG/M3
ARITHMETIC MEAN VALUES BY JOB CATEGORY

BAR CHART OF MEANS

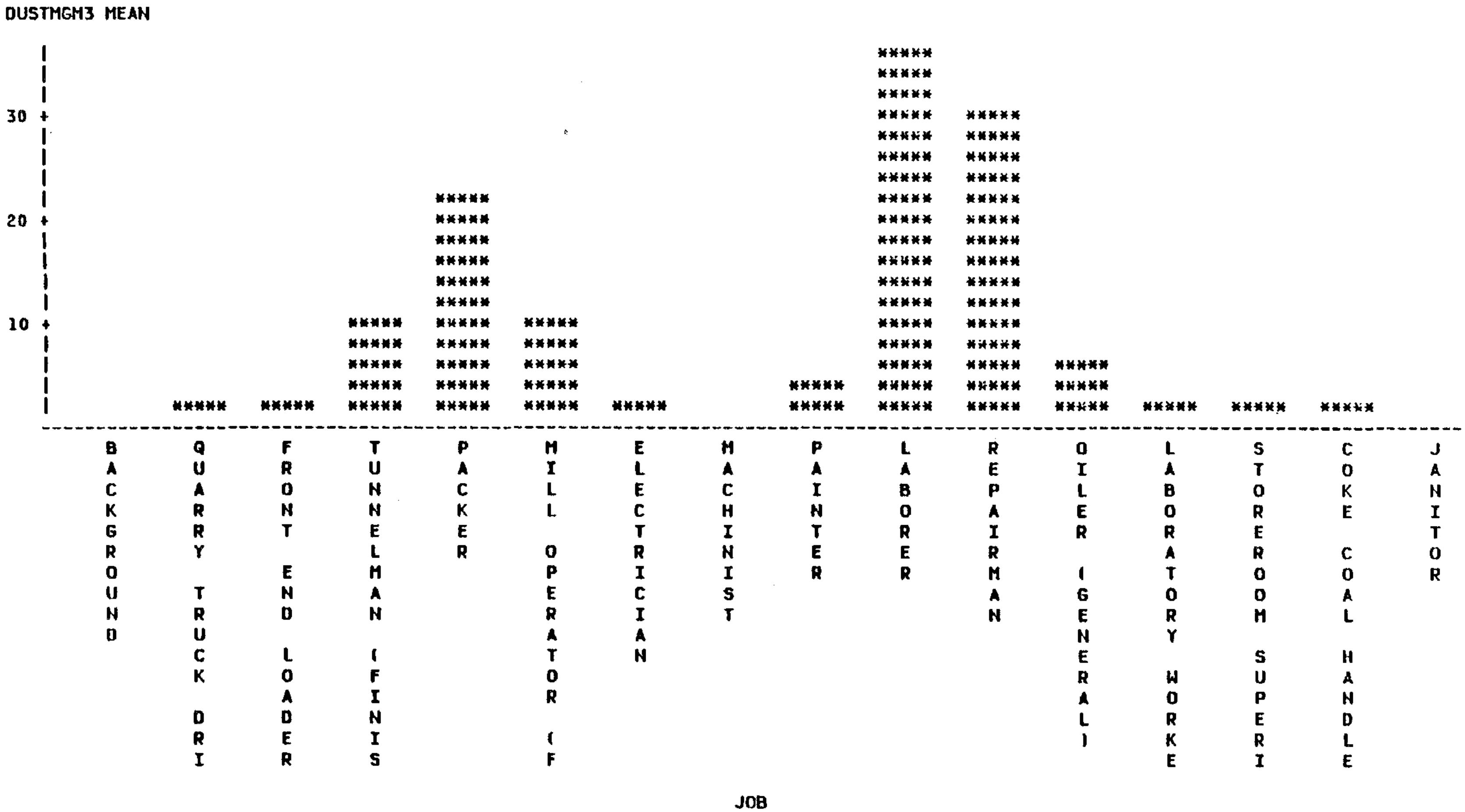


Table 8

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT SAN ANDREAS, CALIFORNIA
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	11MAR81	1	MILLER (RAW)	24	N	N	4	N	N
RAW	11MAR81	1	FRONT END LOADER	19	N	N	13	N	N
RAW	11MAR81	1	QUARRY TRUCK DRIVER	30	N	N	12	N	N
FINISH	12MAR81	1	MILL OPERATOR (FINISH)	68	N	N	47	3	N
FINISH	12MAR81	1	PACKER	88	N	N	65	1	N
FINISH	12MAR81	1	TUNNELMAN (FINISH)	115	N	N	94	3	N
MIX	09MAR81	2	MACHINIST	N	N	N	3	N	N
MIX	09MAR81	2	STOREROOM SUPERINTENDENT	25	9	N	13	N	N
MIX	09MAR81	2	LABORATORY WORKER	43	N	N	35	N	N
MIX	09MAR81	2	REPAIRMAN	87	N	N	52	13	N
MIX	10MAR81	1	OILER (GENERAL)	44	N	N	32	N	N
MIX	10MAR81	1	YARD WORKERS	1159	6	6	773	19	7
MIX	10MAR81	1	ELECTRICIAN	31	N	N	17	N	N
MIX	10MAR81	1	REPAIRMAN	400	N	N	172	7	N
MIX	12MAR81	1	JANITOR	15	N	N	7	N	N
MIX	12MAR81	1	LABORATORY WORKER	N	N	N	9	N	N
MIX	12MAR81	1	LABORER	453	N	N	315	11	N
MIX	12MAR81	1	COKE COAL HANDLER	16	N	N	6	N	N
MIX	12MAR81	1	PAINTER	26	N	N	17	N	N

Table 9

Environmental Investigations Branch

Industrial Hygiene Survey of Cement Workers
Flintkote Cement, San Andreas, California

Summary for Personal Trace Metal Concentrations in
Micrograms per Cubic Meter (ug/m^3)

Metal	N	Means	Std.dev.	Minimum	Maximum
Aluminum	17	156 ug/m^3	289.35	15	1159
Chromium	2	7	1.94	6	9
Cobalt	1	6	0	6	6
Magnesium	19	89	182.32	3	773
Manganeese	7	8	6.61	1	19
Nickel	1	7	0	7	7

Table 10

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT   SAN ANDREAS, CALIFORNIA
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	09MAR81	2	BACKGROUND	N	N	N	2	N	N
BACKGROUND	10MAR81	1	BACKGROUND	N	N	N	2	N	N
BACKGROUND	11MAR81	1	BACKGROUND	18	N	N	2	N	N
BACKGROUND	12MAR81	1	BACKGROUND	N	N	N	2	N	N
RAW	09MAR81	2	BACK END OF KILN	N	N	N	0	N	N
RAW	11MAR81	1	INSIDE DOWN BALL MILL (RAW)	148	65	N	127	32	32
RAW	11MAR81	1	SECONDARY CRUSHER	826	7	5	631	19	N
RAW	11MAR81	1	PRIMARY CRUSHER	57	N	N	154	3	7
RAW	12MAR81	1	PRECIPITATOR OF KILN (WASTE DUST)	932	12	N	442	12	N
CLINKER	09MAR81	2	FRONT END OF KILN	39	N	N	43	N	N
CLINKER	12MAR81	1	FRONT END OF KILN	N	N	N	26	N	N
CLINKER	12MAR81	1	CLINKER COOLER	1188	10	N	704	22	10
FINISH	09MAR81	2	FINISH SILO TUNNEL	160	N	N	11	4	N
FINISH	10MAR81	1	BAGGING	162	7	N	132	2	N
FINISH	10MAR81	1	BULK LOADING SILOS	33	N	N	15	N	N
FINISH	10MAR81	1	BACK END OF KILN	623	N	N	446	10	N
FINISH	12MAR81	1	BULK LOADING SILOS	N	N	N	11	N	N
MIX	09MAR81	2	MAINTENANCE SHOP	N	N	N	2	N	N
MIX	10MAR81	1	COAL BIN	N	N	N	12	N	N

Table 11

Environmental Investigations Branch
Industrial Hygiene Survey of Cement Workers
Flintkote Cement, San Andreas, California

Summary for Area Trace Metal Concentrations in
Micrograms Per Cubic Meter (ug/m^3)

Metal	N	Means	Std. Dev.	Minimum	Maximum
Aluminum	11	380 ug/m^3	428.73	18	1188
Chromium	5	20	25.10	7	65
Cobalt	1	5	0	5	5
Magnesium	19	145	229.32	1	704
Manganeese	8	13	10.78	2	32
Nickel	3	16	14.17	7	32

Table 12

Environmental Investigations Branch
Industrial Hygiene Survey of Cement Workers
Marquette Cement, Rockmart, Georgia

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

		Exposure Categories			
Metals	Bagging	2^o Crusher Quarry	2^o Crusher Quarry	Clinker-Cooler Kiln #1	Mill Room
Aluminum	68.6	204.9	601.7	211.7	40.8
Calcium	1536.8	17570.9	14868.8	6922.6	658.5
Iron	69.3	149.0	385.6	220.3	38.0
Magnesium	52.4	191.7	363.0	196.1	24.9
Manganese	N	5.4	10.7	3.2	N
Sodium	15.9	41.5	33.5	59.5	11.0
Phosphorus	4.0	34.2	139.8	23.0	10.4
Potassium	21.1	52.8	85.6	69.2	9.3
Zinc	N	N	4.37	N	N

The following elements were less than 1.0 ug/filter in the above samples: silver, arsenic, beryllium, cobalt, chromium, copper, litanium, molybdenum, nickel, lead, platinum, selenium, tin, tellurium, thallium, vanadium, yltriam and zirconium.

Table 13

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT   SAN ANDREAS, CALIFORNIA
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	0.99	0.02	0.006	0.882	0.020	0.007	0.0
RAW	RAW MATERIAL	N	N	0.63	N	N	0.410	0.011	N	0.0
RAW	RAW MATERIAL	N	N	0.81	N	N	1.055	0.018	N	0.0
RAW	RAW MATERIAL	5.4	N	1.16	0.02	0.007	1.044	0.018	0.007	0.0
CLINKER	CLINKER	N	N	1.48	N	0.006	1.221	0.020	0.011	0.0
CLINKER	CLINKER	4.2	N	1.55	N	0.008	1.303	0.022	0.011	0.0
CLINKER	CLINKER	N	N	1.58	N	0.007	1.576	0.025	0.009	0.0
FINISH	FINISH	N	N	1.77	N	0.008	1.581	0.024	0.012	0.0
FINISH	FINISH	N	N	2.06	N	0.008	1.465	0.025	0.010	0.0
FINISH	FINISH	N	N	1.73	N	0.008	15.570	0.270	0.120	0.0
FINISH	FINISH	N	N	2.02	N	0.110	1.582	0.033	0.015	0.0
FINISH	FINISH	3.1	N	2.75	N	0.009	1.192	0.023	0.010	0.0
FINISH	FINISH	N	N	1.68	N	0.009	1.319	0.024	0.009	0.0
FINISH	FINISH	N	N	2.71	N	0.007	1.804	0.020	0.008	0.0
FINISH	FINISH	N	N	1.43	N	0.008	1.952	0.023	0.010	0.0
MIX	CLINKER FINISH	N	N	2.01	N	0.008	1.406	0.029	0.009	0.0

Table 14

ENVIRONMENTAL INVESTIGATIONS BRANCH
CEMENT WORKERS MORBIDITY STUDY
FLINTKOTE CEMENT SAN ANDREAS, CALIFORNIA
SOX CONCENTRATIONS

JOB	DATE	SHIFT	AREA	SO4_UGM3	SO3_UGM3	SO2_PPM
SECONDARY CRUSHER	11MAR81	1	RAW	N	N	N
SHAKERS/BELT TRANSFER	11MAR81	1	RAW	N	N	N
DISCHARGE STACK (BOTTOM)	12MAR81	1	RAW	11.13	N	N
PRECIPITATOR OF KILN (WASTE DUST)	12MAR81	1	RAW	1751.3	N	N
CLINKER COOLER	10MAR81	1	CLINKER	35.37	N	N
FRONT END OF KILN	12MAR81	1	CLINKER	13.39	N	N

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.