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Abrons, H. L., W. T. Sanderson, and M. R. Petersen

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An epidemiologic study of the respiratory effects of Portland cement dust was conducted. The cohort consisted of 2,736 cement workers at 16 facilities in the United States. The comparisons consisted of 2,213 individuals in activities not involving dust exposure. Spirometry testing was performed. Respiratory symptom questionnaires were administered. Chest X-rays were taken and examined. Personal sampling for total and respirable dust, quartz (14808607), and oxides of sulfur and nitrogen was performed. Quartz was detected in 14.4 percent of 1,011 respirable dust samples. The median concentration in samples having detectable quartz was 0.079 milligram per cubic meter. Sulfur-dioxide (7446095) concentrations ranged from 0.02 to 0.62 part per million (ppm) and nitrogen-dioxide (10102440) concentrations from 0.06 to 0.44ppm. Cement workers had a significantly elevated adjusted odds ratio for dyspnea, rounded and irregular small X-ray opacities, and pleural abnormalities. None of the ventilatory function variables were significantly different between cement workers and the comparisons. The authors conclude that cement dust exerts little adverse effect on respiratory symptoms and ventilatory function. To determine whether the increase in X-ray abnormalities represents pneumoconiosis or another pathological process would require histological study. There is insufficient evidence to suggest a change in the exposure limit for cement dust

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Respiratory Effects of Portland Cement Dust

Henry L. Abrons, M.D.,
Wayne T. Sanderson, M.S.,
Martin R. Petersen, M.S.

National Institute for Occupational Safety and Health
Division of Respiratory Disease Studies
944 Chestnut Ridge Road
Morgantown, WV 26505

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Respiratory Effects of Portland Cement Dust

INTRODUCTION

The potential for respiratory disease among portland cement plant workers has been investigated in various countries. The first extensive study, conducted in 1928 in the United States[1], was primarily concerned with the incidence of respiratory illness. Although the authors inferred from the radiographs of 53 workers that the inhalation of cement plant dust produced an asymptomatic pneumoconiosis, the prevalence and implications of this finding were not investigated. Subsequently, Gardner et. al.[2] and Sander[3] conducted radiographic surveys which demonstrated parenchymal opacities on the chest films of cement plant workers. Since these and most other radiographic surveys of cement plant workers[4-11] did not use the ILO system[12] for classifying pneumoconiosis on chest radiographs, a modern interpretation of their results is difficult. Only two radiographic studies have been done using the ILO system. Scansetti et. al.[13], considering a profusion of category 1/0 or greater as indicative of pneumoconiosis, found a prevalence of rounded small opacities of 18% and irregular small opacities of 33% in a survey of 100 Italian cement plant workers. There was no control group, and dust measurements were not made. Maestrelli et. al.[14] found irregular small opacities of profusion 0/1 to 1/1 in 14 of 195 exposed Italian cement plant workers but in none of 66 unexposed workers in the same plants.

Most studies of ventilatory function in cement plant workers have lacked

control groups[14, 15], or have failed to account for the effects of smoking on the respiratory system[16], or both[5, 7]. However, there have been several noteworthy exceptions. El-Sewefy et. al.[17] studied ventilatory function in an Egyptian portland cement factory and found that for non-smokers there was no difference in the mean FEV_1/FVC ratio when workers in clean and dusty jobs were compared. For the smokers, the mean ratio was significantly lower for 30-49 year old workers in dusty jobs, although not for other age groups. Rasmussen et. al.[18] found no difference in spirometric measurements when comparing Danish cement plant workers to other blue-collar workers with similar smoking habits. Their study was designed to account for lifetime occupational experience and included former as well as current cement workers. On the other hand, Kalacic[19] found that the FEV_1/FVC ratio for both non-smoking and smoking Yugoslavian cement plant workers was lower than for corresponding controls, and reported that the cement plant workers had more chronic bronchitis with obstruction[9].

Because the previous evidence for an association between cement plant dust and either pneumoconiosis or ventilatory impairment was inconclusive, The National Institute for Occupational Safety and Health (NIOSH) conducted a controlled cross-sectional study using respiratory symptoms, ventilatory function, and chest radiography to investigate the effect of cement plant dust on the respiratory system of workers in the United States.

METHODS

Study population: At the inception of the study (1977), the industry

consisted of 153 plants employing approximately 27,000 workers[20]. Two plant characteristics were felt a priori to be important variables affecting exposure: age (defined as the date of installation of the oldest operating kiln) and the state of the raw materials entering the kiln (wet, dry, or dual), hereafter referred to as the type of process. Therefore, plants were assigned to nine cells according to three age strata and the three process types. The distribution of plants and workers in the industry by plant age and current process type is shown in Table 1. Nineteen plants were initially excluded from the study for various reasons: 5 were closed, 6 had operated too briefly to produce chronic effects, and 8 were deemed unsuitable because of labor-management conflict, lack of cooperation by management, location outside the continental United States, or having more than 500 or fewer than 100 employees. From the remaining 134 plants, a stratified random sample was selected, keeping the number in each cell of the sample roughly proportional to its size in the entire industry. (The intent was to exclude the dual process, but one such plant was inadvertently included in the sample. By coincidence, however, the resulting sample was still proportional in size to the entire industry.) Further exclusion of 15 plants occurred after random selection: 7 because of plant closure, 7 due to lack of cooperation by management, and 1 as a result of labor-management conflict.

Sixteen plants located throughout the country comprised the study sample (Figure 1), and all but one contained quarries. All hourly and salaried workers were invited to participate except at one plant where, for convenience, only hourly production and maintenance workers were studied. The distribution of workers studied (Table 2) was similar to the industry as a

whole with respect to plant age and the current type of raw milling process.

Controls: At control plants, production workers from either the entire plant or selected departments with at least 50 employees were invited for testing; office workers were omitted. Control group A, for symptoms and pulmonary function, consisted of workers in 10 plants in various non-cement industries (Table 3). Since we wished to minimize bias due to self-selection, chest radiography was omitted in this group because of the possibility that it would discourage voluntary participation. The majority of this group worked in machine shop and assembly operations in machinery manufacturing plants. The remainder were employed in the bottling and distribution of soft drinks, in the manufacture of electrical and electronic equipment, and in a dairy. We selected plants which had work environments that were generally free from substantial respiratory hazards. However, it was not our intention that this control group work in a pristine environment since about one-half of the cement workers performed maintenance or laboratory jobs which exposed them to a "background" of inhaled non-cement substances such as solvent vapors. Since our primary aim was to study the effect of cement plant dust per se, we chose Group A to have similar "background" exposures. This was ascertained by carefully detailed industrial hygiene inspection of the control plants. We excluded individuals whose respiratory exposures were likely to have exceeded the cement plant background level (e.g. full-time welders, grinders, and spray painters). These exclusions were made by inspection of the control plants and review of material safety data sheets. In addition, selected measurements were made of the concentrations of various contaminants such as respirable and total dust, volatile hydrocarbons, ammonia, and nitrogen dioxide. Based on

these measurements, 9 individuals were excluded after testing was completed, but without knowledge of their symptoms or spirometry results. Twelve other individuals were excluded because of previous work in cement plants (Table 4).

Control group B, for chest radiography, was a sample of unexposed blue-collar workers in North Carolina. The selection of this group has been described elsewhere[21, 22]. Briefly, the selection criteria were that the industry was quite clean, the work area and job were free from known lung irritants as determined by inspection, respirable dust did not exceed 1.25 mg/m^3 (one-fourth of the threshold limit value for nuisance dust)[23], and individual subjects had histories of fewer than 5 years of previous work in jobs with potential for substantial exposure to dust, gases, or fumes.

Testing procotol: Questionnaires and spirograms were obtained at the cement plants and the group A control plants between July 1979 and February 1982. Spirometry was conducted during the worker's shift. Chest radiographs were taken concurrently at the cement plants and between January 1979 and February 1980 at the group B control plants.

Informed voluntary consent was obtained from each subject. Standing height and weight were measured. A NIOSH modification[22] of the Medical Research Council of Great Britain's questionnaire on respiratory symptoms[24] was administered by trained interviewers, and data were also obtained on demographic characteristics, occupational history, and smoking habits. A translation of the questionnaire was used for Spanish speaking subjects who were not fluent in English. Subjects were classified as

"non-smokers" if they had never smoked, "ex-smokers" if they had quit smoking cigarettes before their previous birthday, "smokers" if they had smoked cigarettes since their last birthday, and "pipe/cigar" users if they currently or formerly had one of these habits and had never smoked cigarettes; those who smoked pipes or cigars and also cigarettes were classified by the cigarette category. Analysis was performed on the following symptoms and syndromes: chronic cough, chronic phlegm, chronic bronchitis with exacerbations, chronic bronchitis with obstruction, dyspnea, wheezing, and asthma. Definitions were made compatible with those used by Kalacic[9] and are shown in Table 5.

Spirometry was performed according to standard procedures[25] with trained technicians and consisted of at least 5 forced expirations into a waterless rolling sealed spirometer (Ohio Model 840) generating flow-volume signals that were electronically recorded. At least three acceptable curves from each subject were required for analysis. Curves not meeting American Thoracic Society standards[25] were rejected. Measurements were converted to body temperature and pressure, saturated (BTPS). The forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and peak expiratory flow (PF) were taken as the maximum measurement of each parameter[25]. Tracings were aligned at maximal inspiration and a composite curve constructed from the highest flow at each lung volume[26], from which the forced expiratory flows after exhalation of 50% and 75% of the vital capacity (FEF_{50} and FEF_{75} respectively) were taken.

Standard postero-anterior chest radiographs were interpreted independently according to the 1971 ILO U/C system[27] by 3 readers who had passed a NIOSH proficiency examination[28]. Radiographs were classified for the profusion

of rounded small opacities, profusion of irregular small opacities, presence of large opacities, and presence of pleural abnormalities (thickening, calcification, or plaques), according to the median reading for each type of abnormality. In cases where only two readers judged the film acceptable for interpretation, the consensus reading was used if there was agreement as to major ILO category, and the film was not classified if there was disagreement. Radiographs whose quality was judged unacceptable by two or more readers also were not classified. Pleural abnormalities were classified only if there was a consensus as to the site. Small opacities were considered present if the median profusion was at least 1/0.

Estimation of exposure: The cement-making process generates dust from quarrying and preparing raw materials; from calcining and grinding clinker; and from blending, packing, and shipping the finished product. Other inhaled contaminants consist of additives (mainly gypsum), products of the combustion of fuel (coal, oil, or natural gas), and exposures encountered in the maintenance of plant and equipment. Inquiry of federal, state, and industry sources revealed that there were no data from which previous environmental exposures could reasonably be estimated. (Samples taken by the Mine Safety and Health Administration (MSHA) for the purpose of monitoring compliance with legal exposure limits tend to represent the high risk jobs rather than the dust concentrations for a broad range of jobs.) For estimating current exposure, sampling was done within two weeks of the medical surveys in all except two plants where it was done 11 months earlier.

Measurements were made of respirable dust, total airborne dust, respirable

crystalline silica, asbestos, and irritant gases. For respirable dust, a full-shift personal breathing-zone air sample was drawn through a 10 mm nylon cyclone and polyvinyl chloride filter at 1.7 Lpm. The cyclone separated the "nonrespirable" fraction of incoming dust from a "respirable" fraction approximating the quantity and particle size distribution of the dust deposited in the alveolar region of the lung[29]. Samples were weighed to the nearest 0.01 mg. The apparatus without the cyclone was used to collect total airborne dust at the same flow rate. In most cases the respirable and total dust samples were collected independently on different workers.

For respirable silica, the personal respirable dust filters were analyzed by x-ray diffraction to measure the content of quartz and cristobalite[30]. The lower limit of quantitation of this technique was 0.03 mg. The silica content of bulk materials was also determined.

For asbestos, area samples were collected for 20 to 30 minutes on open-faced cellulose filters at a flow rate of 1.7 Lpm. The filters were inspected by phase contrast microscopy for the presence of fibers longer than 5 μm and having an aspect ratio of at least 3:1[31]. Since very small fibers may be missed by this method, a random 25% sample of the filters was also inspected by transmission electron microscopy[32]. Bulk material samples from all plant areas were examined for asbestos by polarized light and dispersion staining microscopy[33], and 15 selected samples were analyzed by scanning and transmission electron microscopy, x-ray diffraction, and x-ray fluorescence.

For oxides of sulfur, direct reading instruments were used for preliminary identification of sites of potential exposure. Full-shift area samples for sulfate and sulfite particulates and sulfur dioxide (SO_2) gas were then collected and measured by ion chromatography[34]. The lower limits of quantitation were 0.005 mg for sulfates, 0.01 mg for sulfites, and 0.01 ppm for SO_2.

For nitrogen dioxide (NO_2), passive dosimeters were used to determine both personal and area full-shift time-weighted average exposures[35].

Jobs were classified according to the duties performed and the plant area with which they were most closely associated. The plant areas were designated "raw", "clinker", "finished", and "mixed", reflecting qualitative differences in the types of dust generated by the cement making process. The raw area consisted of the quarry, primary crusher, raw mills, and raw material handling. The clinker area included the discharge end of the kiln and the clinker cooler. The finished area comprised the finished cement mills, blending, packing, and storage. The mixed area included the yard, laboratory, offices, and plantwide maintenance and supervision. When the raw and finished mills were located in the same area, they were counted in the mixed area.

To determine the optimum strategy for sampling, a pilot environmental survey was conducted at 5 plants. Workers from various jobs, shifts, and plant areas were randomly selected and sampled for respirable and total dust on two consecutive days over a 4 day period. Analysis of components of variance demonstrated that there was a fairly large variation in respirable

dust concentration from job to job and day to day, but that inter-subject variation alone was small. Thus, for the full study, as many randomly chosen jobs as possible were sampled Within jobs, individuals were selected for sampling on the basis of availability. Sampling was conducted over three days on the first (day) shift and over one day on the second and third shifts.

The distribution of the samples with respect to dust concentration was closer to a log-normal than to a normal distribution, with skewness to the right (Figures 2 and 3). This appeared to be true for each job within each plant, as well as for all samples. When more than one sample per job was obtained, the geometric mean was used to determine the dust level for job-within-plant. In some cases only one sample per job was taken. For each plant, all individuals in a job, whether sampled or not, were assigned the determined dust concentration as their current exposure. The distributions of these dust concentrations are shown in Figures 4 and 5.

Sample Size: Sample size was based on the hypothesis of an equal prevalence of chronic bronchitis with obstruction in cement workers and a comparison group using a two-tailed test. As a conservative estimate, a prevalence of 20% was used, based on the prevalence 11.2% observed by Kalacic[9] in Yugoslavian cement workers. At the 5 per cent level of significance, the power of the test was set at 95 per cent to detect a hypothetical difference in prevalence between the groups of 5%. The minimum sample size was determined to be 3328 for the combined sample of the cement workers and the comparison group.

Data Analysis: For ventilatory function, linear models analysis was used, with adjustment for sex, race, age, height, smoking status, and pack-years of cigarettes. The model was:

$$y = b_0 + \text{sex} + \text{race} + b_1(\text{age}) + b_2(\text{height}) + \text{smoking status} +$$
$$\text{pack-years}*\text{smoking status} + \text{age}*\text{smoking status} + \text{plant} + \text{exposure},$$

where y is a ventilatory function measurement, and * denotes an interaction term. "Plant" was included in the model to adjust for possible inter-plant differences in outcome resulting from unidentified confounding factors, such as population differences or unmeasured exposures. This adjustment does not obscure or remove effects due to the measured exposure variables, namely job tenure and current dust concentration. Tests of significance were made with the F test. For comparisons with controls, plant was nested within group and formed the denominator of the F test. For analyses involving only cement workers, plant was simply treated as a confounder.

For symptoms, logistic analysis was used. This was similar to the linear models analysis; however the dependent variable was $\ln[P/(1-P)]$, where P is a symptom prevalence. Adjustment was made for sex, age, smoking status, and pack-years of cigarettes, but not for race. The model was:

$$\ln[P/(1-P)] = b_0 + b_1(\text{age}) + \text{sex} + \text{smoking status} +$$
$$\text{pack-years}*\text{smoking status} + \text{age}*\text{smoking status} + \text{exposure}.$$

Plant was excluded from the model because some plants had zero prevalences for some symptoms, which would have prevented estimation and testing. Outcomes were expressed as adjusted odds ratios and tested for significance by the likelihood ratio chi-square test.

For radiographic abnormalities, the model and method of analysis were the same as for symptoms, except that adjustment for sex was omitted because no radiographic abnormalities occurred among the women, and sex was not expected to be related to radiographic abnormalities. Also, pipe/cigar smokers had no abnormalities, and they were excluded from this analysis so that estimation and testing could be performed.

Three types of comparisons were made. The first compared cement workers with controls by substituting the respective group for "exposure" in the models. The second compared cement workers for the effects of plant area, using the plant area in which each cement worker had served the majority of his cement plant tenure, as determined from the occupational history, as the exposure variable. If no single area accounted for a majority, the worker was placed in the "mixed" category. Because our interest was mainly in the effects of chronic exposure, this analysis was done only for cement workers with at least 8 years of tenure . For the third type of comparison, an exposure-response surface was fitted for cement workers using current respirable or total dust level, job tenure, and the interaction (i.e. product) of dust level and tenure. Tenure was partitioned into current cement job and previous cement jobs because the current dust levels probably had less validity for jobs performed in the past. In the exposure-response analysis, the term for exposure in each model was replaced by:

$$b_3D + b_4(CJT) + b_5(PJT) + b_6(D*CJT) + b_7(D*PJT),$$

where D = current respirable dust (RD) or total dust (TD) concentration ($\mu g/m^3$), CJT and PJT = tenure (months) in current and previous cement jobs respectively, and D*CJT and D*PJT are the interactions of current dust

concentration with current and previous job tenure respectively. The tests were accomplished by comparing models with and without the exposure terms. The first step was to test the five terms in combination. If this was not significant, further testing was not performed; if significant, the interactions and then the main exposure terms were tested in various combinations and non-significant terms were eliminated. The final model contained only significant terms and those required to make the model hierarchical.

Additional analyses were performed for silica exposure in relation to rounded small opacities and to ventilatory function. Three methods were used to define silica exposure. The first method divided subjects into those currently working in "high silica" versus "low silica" jobs. High silica jobs were those in which at least 10% of the respirable dust samples showed detectable silica. Low silica jobs had less than 10% showing detectable silica but also had at least 10 samples taken. The rest of the jobs were not included. The second method used the current concentration of respirable silica, and only included subjects currently working in jobs with detectable silica. The third method divided all subjects according to total tenure in the raw and mixed plant areas. The tenure groups were 0-60 months, 61-120 months, 121-180 months, and more than 180 months.

An estimate of statistical power was made for the comparisons of cement workers and controls with respect to FEV_1, chronic phlegm, and chronic bronchitis with obstruction. This was done by subtracting the estimated group difference, which was found when the analysis was performed, from each cement worker's predicted value (based on the fitted model), and then adding the difference of interest to this result. Random normal numbers with the

appropriate variance were generated using RANNOR and the Statistical Analysis System[36], added to the above sum, and the test was rerun 20 times using this final sum as the dependent variable. The power estimate was the proportion of runs for which the test was statistically significant. This procedure takes into account any interrelationships among the independent variables.

In all cases, differences were considered significant when the p values were less than or equal to 0.05.

RESULTS

Current Dust Exposure: One thousand eleven personal respirable dust samples and 211 personal total dust samples were collected. Dust data are summarized in Table 6. For these and other contaminants, the proportion of samples exceeding the existing and recommended exposure limits are shown in the various tables. Analysis of variance (based on the logarithms of the dust measurements, due to the skewness of their distribution) showed that individual measurements were significantly influenced by job, shift, and plant for respirable dust, and by job alone for total dust (Table 7). Plant age, type of raw milling process, and the interaction of age and process type did not influence the concentration of either type of dust. The respirable dust analysis probably has more power than that for total dust because it is based on more samples.

Quartz was detected in 14.4% of the personal respirable dust samples which

were analyzed for crystalline silica. The median concentration in samples having detectable quartz was 0.079 mg/m^3 (Table 8). Respirable quartz was found most frequently and in the highest concentrations in samples from the raw area, followed by the mixed, clinker, and finished areas. Analysis of bulk materials for quartz gave the same ranking of plant areas. The proportion of samples with detectable quartz varied significantly from plant to plant ($p \leq 0.01$), probably due to differences in raw materials. No cristobalite was found in the personal or the bulk samples.

Other Contaminants: In 195 area samples of airborne dust and 292 bulk material samples, no asbestos or other mineral fibers were found. Data on oxides of sulfur and NO_2 are given in Table 9. Within samples, the levels of sulfates, sulfites, and SO_2 were not correlated. Compared to existing and recommended exposure limits, levels of SO_2 and NO_2 were low.

Population characteristics: Three thousand one hundred fifty-one cement workers were invited to take part in the study and 86.9% participated (Table 4). Participation rates were 73.3% for control group A and 55.2% for control group B, the latter possibly reflecting low incentive for having a chest radiographic exam, together with concern about the health effects of radiation. A follow-up questionnaire on the group B non-participants, described previously[21,22], suggested that overall bias caused by non-participation was small. Two cement workers were excluded from analysis because of missing questionnaire data. Twenty-one group A and 257 group B controls were excluded because of substantial exposure to respiratory hazards or previous work in cement plants. The cohort for analysis consisted of 2736

cement workers, 755 group A controls, and 1458 group B controls. Spirograms and chest radiographs were excluded from analysis if they did not meet the criteria previously described (see Methods). Also, some individuals declined to have radiographs taken. Table 4 shows the number of tests available for analysis.

The demographic characteristics of the cement workers and controls are shown in Table 10. The control groups were younger and shorter than the cement workers and had a higher proportion of women (possibly explaining why they were shorter).

Table 11 shows the smoking habits of the cohort. The cement workers had proportionally more ex-smokers, fewer non-smokers, and about the same proportion of smokers as the controls. Average cigarette consumption (in pack-years) was higher among the cement workers.

The inter-plant variation of chronic bronchitis prevalence and of FEV_1 among the group A control plants was tested with the logistic and linear models after adjusting for confounding variables. There was no significant inter-plant variation, demonstrating that with respect to these characteristics the group A plants can be regarded as samples from a single population.

Cement workers vs. controls: The crude prevalences and adjusted odds ratios of selected symptoms and syndromes in cement workers and group A controls are shown in Table 12. Cement workers had a significantly elevated

adjusted odds ratio for dyspnea ($p \leq 0.05$). This was unaltered by adding the interaction of smoking status and exposure, indicating an equivalent effect in all smoking categories. No significant differences were found in the prevalence of chronic cough, chronic phlegm, chronic bronchitis with exacerbations, chronic bronchitis with obstruction, wheezing, or asthma.

The crude prevalences and adjusted odds ratios of radiographic abnormalities in cement workers and group B controls are shown in Table 13. For comparison, the cement workers were restricted to subjects with no significant prior dust, gas, or fume exposure outside the cement industry, according to the same criteria used for the controls. The cement workers had significantly higher adjusted odds ratios for rounded and irregular small opacities ($p \leq 0.05$) and pleural abnormalities ($p \leq 0.01$). The significances were unchanged by adding an index of obesity (weight/height^2)[37] to the model, demonstrating that obesity did not confound the radiographic results.

Details concerning pleural abnormalities in the cement workers are shown in Table 14. The association between pleural abnormalities and irregular opacities was examined because both can arise from asbestos exposure. Of the 42 cement workers with pleural abnormalities, 2 had irregular opacities, 2 had both rounded and irregular opacities, and the remaining 38 had no opacities. Only the subject with bilateral calcified pleural plaques had a history of asbestos exposure (defined as a minimum of 5 years), and there was no significant association between such a history and either irregular small opacities or pleural abnormalities (Table 15).

Because zero prevalences were present in some subgroups, the logistic model could not be used to test for interactions with smoking status. Instead, a breakdown of the data by smoking status was made, and it showed that smoking cement workers had a significantly greater proportion of all radiographic abnormalities than their blue collar counterparts, whereas ex- and non-smoking cement workers did not (Table 16).

None of the ventilatory function variables was significantly different between cement workers and group A controls after adjustment for confounding factors (Table 17).

Effect of Plant area: There was no relationship between plant area and the prevalence of symptoms or radiographic abnormalities. For workers who spent the majority of their tenure in the mixed area, the adjusted mean FVC was larger, 4.35 L, compared to 4.24 L for raw, 4.23 L for finished, and 4.17 L for clinker ($p \leq 0.01$). The interaction of plant area and smoking status was not significant, indicating that the effect was equivalant in all smoking categories. There was no relationship between plant area and the other ventilatory function variables.

Exposure-response relationships: Significant exposure-response associations are shown in Table 18. The prevalence of chronic phlegm was positively related to tenure ($p \leq 0.05$) among the 2298 subjects with respirable dust measurements. The adjusted odds ratio (OR_{adj}) relative to zero exposure was:

$$OR_{adj} = e^{0.0020(PJT)}.$$

The relationship was also significant among the 1040 subjects with total dust measurements, but the estimated coefficients are less reliable because the sample size was smaller. The prevalence of wheezing was positively related to current respirable dust concentration and tenure ($p \leq 0.05$). The adjusted odds ratio was:

$$OR_{adj} = e^{0.1205(RD) + 0.0020(PJT)}.$$

For both chronic phlegm and wheezing, the interactions of the significant exposure terms and smoking status were not significant, indicating that the odds ratios were equivalent for all smoking categories. Values of the odds ratios for various lengths of tenure and current concentrations of dust are shown in Table 18. Other symptoms were not significantly related to tenure or current dust concentration.

Rounded and irregular small opacities were not related to current respirable or total dust concentration or to tenure. The prevalence of pleural abnormalities was related to current total dust concentration, current job tenure, and previous job tenure, with the effect of dust dependent on the current job tenure ($p \leq 0.01$). The adjusted odds ratio was:

$$OR_{adj} = e^{0.0819(TD) + 0.0128(CJT) + 0.0078(PJT) - 0.0009(D*CJT)}.$$

The interactions between the significant exposure variables and smoking status were not significant, indicating that the exposure effects were equivalent for all smoking categories. Values of the odds ratio for various dust concentrations and tenures are shown in Table 18. Regardless of previous job tenure, the odds ratio increased with increasing current job tenure at low dust levels, and with increasing dust level for low current job tenure. However, a transition occurred between 5 and 10 years of current job tenure,

and between 10 and 20 mg/m^3 of current total dust concentration, such that the odds ratio declined with higher current job tenure and higher dust.

Among cement workers, the only measurement of ventilatory function that correlated with exposure was peak flow, which was negatively related to current respirable dust concentration ($p \leq 0.01$, regression coefficient = $-103.2\ ml \cdot sec^{-1}/mg \cdot m^{-3}$). Neither tenure nor the interaction of dust concentration and tenure were significant. Thus, there was no evidence that individuals with longer exposure were more severely affected. The relationship between peak flow and respirable dust was unchanged after adjustment for the history of non-cement dust, gas, and fume exposure. The interaction of respirable dust concentration and smoking status was not significant, indicating an equivalent effect in all smoking categories.

Effect of silica exposure: When silica exposure was defined by any of the three methods, in no case was it related to the prevalence of rounded small opacities. Incorporating the third method for defining silica exposure (based on total tenure in the raw and mixed areas) into the analysis of ventilatory function, no significant relationships were found between silica exposure and either FEV_1 or FVC.

DISCUSSION

This is the first controlled epidemiologic study of the respiratory effects of portland cement plant dust in the United States. We observed no difference in symptoms between cement workers and controls, with the exception

that a higher proportion of cement workers claimed to have dyspnea. Because there were no differences in ventilatory function, this may merely reflect a greater propensity of an exposed population to perceive and report symptoms.

Our results with respect to ventilatory function agree with those of Rasmussen et. al.[18], but with respect to both ventilatory function and symptoms, they differ from those of Kalacic[19]. Kalacic's chest symptom data are compared with ours in Table 19. If our smoking-specific rates were applied to the Yugoslavian cohort, the adjusted Yugoslavian prevalence of chronic bronchitis with obstruction would be 4.6%, which is significantly ($p \leq 0.01$) lower than the 11.2% observed in Kalacic's study. Therefore, the higher Yugoslavian prevalence is not due to differences in smoking, but probably reflects their considerably higher dust exposure (Saric M. Unpublished observations).

It is unlikely that our negative findings in comparing cement workers and controls with respect to most symptoms and ventilatory function are due to the masking of true differences. First, it is improbable that chronic health effects were missed in the cement workers due to low tenure or exposure, because the median tenure of the cement workers was 10.9 years (see Figure 6) and because only 20.6% worked in nonproduction (office, laboratory, or managerial) jobs. Second, control group A was selected with great care so that the nature and intensity of the background exposures to inhaled substances, and the proportion of the group subjected to them, closely resembled the background exposures of the cement workers to non-cement inhaled substances. Had we not chosen group A controls with such background exposures, we could not have tested the respiratory effects of cement dust per

se on symptoms and ventilatory function with any validity, since any observed differences could have been attributed to the cement workers' exposure to non-cement inhaled substances as well as to cement dust. That we were consistently able to select group A controls with similar low levels of exposure to non-cement inhaled substances is supported by the lack of significant differences in adjusted chronic phlegm prevalence and FEV_1 among group A control plants. Third, the likelihood of failing to detect true differences in key variables due to inadequate sample size was low. For FEV_1, the estimated power was 0.90 for a true difference of 0.1 liters. For chronic phlegm, the estimated powers were 0.65 and 1.00 for true odds ratios of 1.3 and 1.6 respectively. For chronic bronchitis with obstruction, the power was 1.00 for a true odds ratio of 2.67, representing the relative risk corresponding to a 0.05 elevation in prevalence among cement plant workers over group A controls. Thus it is unlikely that differences as large as 0.1 liters for FEV_1, $OR_{adj}=1.6$ for phlegm, or a 0.05 elevation in the prevalence of chronic bronchitis with obstruction were actually present. Finally, we feel that the validity of our findings is strengthened by the high rate of participation by the cement workers and by the careful adjustment for confounding variables.

However, as a cross-sectional study, our data is subject to inherent potential bias due to the out-migration of susceptible individuals from the exposed population (the "survivor effect"). The influence of this potential bias cannot be estimated without either a longitudinal study or the examination of "drop-outs" from the industry, which we did not do.

Our finding of an increase in the radiographic appearance of pneumoconiosis in portland cement plant workers is consistent with previous observations. Whether this represents actual pneumoconiosis or another process requires histologic confirmation. The possibility of pneumoconiosis is suggested by a case reported by Pimentel and Menezes[38] showing pulmonary granulomas containing inclusions of cement. The small opacities found in our study were predominantly in smokers, which may reflect a deleterious effect of cigarette smoke on the clearance of inhaled dust or an augmented tissue response. Our data do not demonstrate a relationship between small opacities and the current level of dust exposure. However, the data do not permit a fully adequate assessment of exposure-response relationships for chronic effects. Although also not fully adequate, such relationships are usually approached by estimating cumulative exposure based on the duration of exposure and on dust levels in the past. Dust levels in the cement plants studied by Gardner[2] in the 1930's were higher than levels observed in our study, allowing for differences in methods of sampling and measurement. However, there are no data on dust levels over the intervening years for the industry in general or the subjects of this investigation in particular. Therefore, even the most carefully performed historical reconstruction of environmental conditions would be arbitrary, and cumulative exposures could be seriously underestimated or overestimated in an unpredictable manner. Consequently, we believe that the obstacles to calculating a reasonable and unbiased estimate of cumulative exposure are insurmountable. Instead, we have used current dust concentrations, tenure, and their interactions to explore what might have been found had cumulative exposure data been available. If current and previous dust levels were related, using the interaction (or

product) of current dust level and tenure in the analysis would resemble the use of cumulative exposure; if they were unrelated, then chronic effects should still be related to tenure. This in either case, if a health effect was related to cumulative exposure, tenure should be a significant explanatory variable. We found no relationship between tenure and small opacities. Thus, we conclude either that small opacities are not strongly related to cement plant dust exposure, or that we were unable to demonstrate such a relationship because the proportion of small opacities in our sample, although elevated above control levels, was low.

An unexpected finding was the association between cement plant dust exposure and pleural abnormalities, mostly bilateral pleural thickening. This was not an artifact of obesity and, except in one subject, could not be explained by asbestos exposure. Pleural abnormalities were exposure-related in terms of both tenure and current dust level (with the latter possibly being related to previous dust level). Because all of the radiographic changes are presumably chronic, they are probably more reflective of previous than current dust conditions. Our data are consistent with this supposition if, for workers with short current job tenure, current total dust concentration reflects the relative magnitude of previous exposure (Table 18). For workers with long current job tenure, the relationship between pleural changes and cement plant dust exposure suggests a survivor effect (i.e., only less susceptible individuals may have tolerated high dust concentrations) (Table 18).

It is conceivable that the radiographic differences between the cement

workers and the group B controls could be due to interpreter differences. There were 3 interpreters for the cement films and 11 for the control films (three of which interpreted each film), with one interpreter common to both groups. With respect to the other cement film interpreters, this interpreter's estimated prevalences fell in the middle position for both small rounded and small irregular opacities, and in the lowest position for pleural abnormalities. The fact that his estimated prevalences were higher for cement workers than controls (small rounded opacities: 1.73% compared to 0.00%; small irregular opacities: 1.51% compared to 0.16%; and pleural abnormalities: 2.16% compared to 1.13%) suggests that the higher prevalences in the cement workers were not an artifact of interpreter bias.

Considering the lack of differences between the cement workers and the controls, we feel that the analysis of other exposure-response relationships is of minor interest. However, the association of chronic phlegm with previous job tenure suggests a possible relationship between cement plant dust exposure and "industrial bronchitis"[39] which was nonobstructive since there was no difference in FEV_1. The exposure-related reduction in peak flow, which represents a 1 to 2% drop per $mg \cdot m^{-3}$ of respirable dust, was possibly an acute transient effect of dust on the large airways since it was not related to tenure. However, Saric observed negligible change in the FEV_1 over a work shift in Yugoslavian cement workers exposed to 3.3 to 30 mg/m^3 of respirable dust, and no significant change in airways resistance after similar concentrations were administered in an exposure chamber (Saric M. Unpublished observations).

Our environmental data show that 5% of samples exceeded the current

exposure limit for respirable dust, 19% exceeded the limit for total dust and 8.1% exceeded the limit for respirable silica[40] (Tables 6 and 8). Our sample of 16 cement plants was representative of the United States industry with respect to plant age, process type, and geographic distribution. We found that dust concentrations were a function of plant, job, and shift, but were not influenced by plant age or type of process (Table 7). We found no asbestos in our environmental samples.

In conclusion, we found little adverse effect of cement plant dust on respiratory symptoms and ventilatory function. The prevalence of radiographic abnormalities consistent with pneumoconiosis in cement workers was low but was significantly elevated. To determine whether this represents pneumoconiosis or another pathologic process would require histologic study. The prevalence of pleural abnormalities was also low, but significantly elevated over that of controls, and it was also related to total dust and tenure. Asbestos does not appear to be a possible cause of this excess because the workers with these abnormalities (except for one) had no known present or previous exposure to asbestos. If confirmed in other studies, the elucidation of the relationship between cement plant dust exposure and pleural changes will be of interest. Presently, however, we do not feel that there is sufficient evidence to suggest a change in the exposure limit for cement dust.

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Table 1. U.S. Portland Cement Industry (1977)

Composition by Age of Plant and Type of Process*

	Before 1941		1941-1960		1961-1976		All Ages	
	Plants	Workers	Plants	Workers	Plants	Workers	Plants	Workers
Wet	19	2630 (9.8%)	32	6130 (22.8%)	36	5517 (20.5%)	87	14,277 (53.1%)
Dry	9	1489 (5.5%)	22	5296 (19.7%)	29	4200 (15.6%)	60	10,985 (40.8%)
Dual	1	207 (0.8%)	4	281 (4.8%)	1	148 (0.6%)	6	1,636 (6.1%)
Total	29	4,326 (16.1%)	58	12,707 (47.2%)	66	9,865 (36.7%)	153	26,898 (100.0%)

* Reference 20. Data are approximate.

Table 2. Cement Workers Examined (1979-1982)

Distribution by Age of Plant and Type of Process

	Before 1941	1941-1960	1961-1978	All Ages
Wet	250 (9.1%)	545 (19.9%)	325 (11.9%)	1120 (40.9%)
Dry	202 (7.4%)	604 (22.1%)	570 (20.8%)	1376 (50.3%)
Dual	0 (0.0%)	242 (8.8%)	0 (0.0%)	242 (8.8%)
Total	452 (16.5%)	1391 (50.8%)	895 (32.7%)	2738 (100.0%)

Table 3. Control Group A

Type of industry	State	No. Examined
Turbine generator manufacturing	NY	100
Soft drink bottling & distribution	GA	79
Soft drink bottling & distribution	CA	87
Dairy	AR	74
Electrical controls manufacturing	TX	59
Electronic components manufacturing	SD	78
Farm machinery manufacturing	IA	61
Motor vehicle parts manufacturing	IN	75
Turbine generator manufacturing	SC	85
Rolling mill machinery manufacturing	CA	78
		776

Table 4. Numbers of Subjects and Tests

	Cement Workers	Control Group A	Control Group B
No. Invited	3151	1058	3108
Absent	255 (8.1%)	94 (8.9%)	44 (1.4%)
Refused	158 (5.0%)	188 (17.8%)	1349 (43.4%)
No. Examined	2738 (86.9%)	776 (73.3%)	1715 (55.2%)
Excluded	2	21	257
Cohort Size (N)	2736	755	1458
No. of Tests			
Questionnaires	2736	755	1458
Spirograms Meeting ATS Standards*	2607	729	NA
Radiographs Classified*	2651	NA	1437
No. Assigned Personal Dust Levels			
Respirable Dust	2298	NA	NA
Respirable Silica	2298	NA	NA
Total Dust	1040	NA	NA

* See Methods

Table 5. Definitions of Symptoms and Syndromes

Symptom	Definition
Chronic Cough	Cough part of day or entire day for at least three months each year
Chronic Phlegm	Phlegm part of day or entire day for at least three months each year
Chronic Bronchitis with Exacerbations	Chronic phlegm and at least 1 exacerbation* in past 3 yrs
Chronic Bronchitis with Obstruction	Chronic phlegm entire day and:

FEV_1/FVC	Age
≤ 0.79	25-29
≤ 0.76	30-39
≤ 0.74	40-49
≤ 0.71	50-59

Dyspnea	Dyspnea walking on level ground
Wheezing	Wheezing on most days or nights
Asthma	Attacks of dyspnea with wheezing

* An episode of increased cough or phlegm lasting for at least 3 weeks.

Table 6. Personal Dust Samples in the Cement Workers

	N	Mean Concentration* mg/m^3	95% Confidence Limits for the Mean, mg/m^3	Range mg/m^3	Samples Greater than MSHA Limit+
Respirable Dust	1011	0.57 (3.60)	$0.53 \leq \mu \leq 0.62$	0.01 - 46.22	5%
Total Dust	211	2.90 (4.35)	$2.38 \leq \mu \leq 3.54$	0.01 - 78.61	19%

* Geometric mean (SD).
+ Reference 40.

Table 7. Personal Dust Concentration: Analysis of Variance*

Source of Variability	Degrees of Freedom	Mean Square	p+
Respirable Dust:			
Age	2	11.30	0.30
Process	1	3.86	0.51
Age-by-Process Interaction	2	3.11	0.69
Plant**	9	8.07	0.0001
Shift	2	5.08	0.0093
Job	106	4.17	0.0001
Error	801	1.08	
Total Dust:			
Age	2	1.47	0.62
Process	1	1.51	0.49
Age-by-Process Interaction	1	1.59	0.48
Plant**	8	2.91	0.14
Shift	1	0.001	0.98
Job	64	2.63	0.05
Error	115	1.86	

* Excludes measurements in the dual process plant and 3 zero values.
\+ p value for the F test.
** Nested within age-by-process cell.

Table 8. Personal Quartz Samples in the Cement Workers

Plant Area	Mean Respirable Dust* mg/m^3	No. of Samples	Samples with Detectable Quartz	Median Quartz+ mg/m^3	Percent of All Samples Exceeding: MSHA Limit**	NIOSH Standard++
Raw	0.48	215	60 (27.9%)	0.085	16.4%	21.4%
Clinker	0.48	133	11 (8.3%)	0.072	4.5%	5.3%
Finished	0.85	177	5 (2.8%)	0.056	1.7%	1.7%
Mixed	0.55	482	69 (14.3%)	0.081	7.7%	10.8%
All	0.57	1007	145 (14.4%)	0.079	8.1%	10.8%

* Geometric mean.
\+ For samples with detectable quartz.
** Reference 40.
++ Reference 41.

Table 9. Oxides of Sulfur and Nitrogen Dioxide in the Cement Workers

Species	Samples	Samples with Dectable Species	Concentration				Percent of All Samples Exceeding:	
			Median		Maximum		MSHA Limit	NIOSH Standard
Sulfates	91	67 (73.6%)	38	$\mu g/m^3$	2208	$\mu g/m^3$	*	*
Sulfites	91	7 (7.7%)	34	$\mu g/m^3$	221	$\mu g/m^3$	*	*
SO_2	91	65 (71.4%)	0.02	ppm	0.62	ppm	0%+	1.1%**
NO_2	261	236 (90.4%)	0.06	ppm++	0.44	ppm++	***	+++

* No limit or recommended standard.
\+ Reference 40.
** Reference 42.
++ Full-shift time-weighted average concentration.
*** 5 ppm ceiling (15 minute) concentration(40).
+++ 1 ppm ceiling (15 minute) concentration(43).

Table 10. Demographic Data

A. Data for Analysis of Symptoms and Ventilatory Function

	Cement Workers	Control Group A
N	2736	755
Age, yr*	40.9 (11.5)	36.3 (12.0)
Height, cm*	173.8 (7.2)+	172.7 (7.6)
Sex, % Male	95.1	89.1
Race, %		
White	81.8	85.8
Black	7.3	6.4
Hispanic	10.5	7.2
Other	0.4	0.7
Unknown	0.1	0.0
Education, yr*	11.8 (2.3)**	12.1 (2.0)++

B. Data for Analysis of Chest Radiographs

	Cement Workers	Control Group B
N	1589	1458
Age, yr*	38.4 (11.7)	33.9 (12.7)
Height, cm*	173.8 (7.5)***	167.5 (9.1)+++
Sex, % Male	93.1	50.1
Race, %		
White	80.7	52.7
Black	7.5	43.8
Hispanic	11.4	0.1
Other	0.3	3.1
Unknown	0.1	0.3
Education	12.1 (2.2)****	10.9 (2.2)++++

* Mean (SD)
\+ N=2733
** N=2728
\++ N= 753
*** N=1586
\+++ N=1457
**** N=1585
\++++ N=1455

Table 1. Smoking Data

	Cement Workers		Control Group A		Control Group B	
	No.	Pack-years mean	No.	Pack-years mean	No.	Pack-years mean
Non-smokers	664 (24.3%)	0	260 (34.4%)	0	528 (36.2%)	0
Ex-smokers	742 (27.1%)	22.1*	160 (21.2%)	17.4	174 (11.9%)	13.0
Smokers	1193 (43.6%)	28.8+	309 (40.9%)	20.6**	712 (48.8%)	12.3++
Pipe/cigar	117 (4.3%)	0	21 (2.8%)	0	26 (1.8%)	0
Unclassified***	20 (0.7%)	NA	5 (0.7%)	NA	18 (1.2%)	NA
	2736 (100.0%)		755 (100.0%)		1458 (100.0%)	

* N = 733 subjects.
\+ N= 1171 subjects.
** N = 307 subjects.
++ N = 710.
*** Deleted from analysis.
NA Not applicable.

Table 12. Respiratory Symptoms and Syndromes

	Crude Prevalence		Adjusted Odds Ratio*	p+
	Cement Workers	Control Group A		
Chronic Cough	15.4%	13.8%	0.96	0.73
Chronic Phlegm	18.2%	16.1%	1.06	0.65
Chronic Bronchitis with Exacerbations	5.8%	4.1%	1.41	0.08
Chronic Bronchitis with Obstruction	4.1%	3.0%	1.18	0.54
Dyspnea	5.4%	2.7%	1.60	0.05
Wheeze	8.5%	7.7%	0.93	0.63
Asthma	8.7%	8.9%	0.88	0.40

* Odds ratios adjusted for age, sex, and smoking. Subjects with unclassified smoking deleted.

+ p value for testing the hypothesis that $OR_{adj}=1$, using the likelihood ratio chi-square test.

Table 13. Radiographic Abnormalities

	Cement Workers		Control Group B		Adjusted	p+
	Total	Prevalence	Total	Prevalence	Odds Ratio*	
Rounded Small Opacities						
Whole Group	2643	21 (0.79%)				
No Prior Exposure**	1462	12 (0.82%)	1392	2 (0.14%)	4.67	0.03
Irregular Small Opacities						
Whole Group	2646	29 (1.10%)				
No Prior Exposure**	1462	15 (1.02%)	1388	1 (0.07%)	6.45++	0.03
Large Opacities						
Whole Group	2650	0 (0.00%)				
No Prior Exposure**	1466	0 (0.00%)	1393	0 (0.00%)	1.00	1.00
Pleural Abnormalities						
Whole Group	2641	42 (1.59%)				
No Prior Exposure**	1459	24 (1.64%)	1393	3 (0.22%)	5.03	0.003

* Odds ratios adjusted for age and smoking. Subjects with unclassified smoking deleted.

\+ p value for testing the hypothesis that $OR_{adj}=1$, using the likelihood ratio chi-square test.

** Pipe/cigar users had zero prevalence and were deleted to obtain convergence of the logistic model.

++ Non-smokers had zero prevalence and were deleted to obtain convergence of the logistic model.

Table 14. Pleural Abnormalities in the Cement Workers

Site	Thickening	Plaques		Mixed*
		Calcified	Uncalcified	
Unilateral	11	0	0	0
Bilateral	29	1	0	1
All Sites	40	1	0	1

* Thickening (one reader) and calcified plaques (another reader).

Table 15. Radiographic Abnormalities versus Asbestos Exposure in the Cement Workers

Asbestos Exposure	Irregular Small Opacities Pos./Neg.	% Pos.	p*	Pleural Abnormalities Pos./Neg.	% Pos.	p*
Yes+	0 / 69	(0 %)	0.93	1 / 68	(1.5%)	1.00
No	29 / 2548	(1.1%)		41 / 2531	(1.6%)	

* p value for testing the hypothesis that the exposed have the same prevalence as the unexposed, using the Fisher's exact test.
+ History of exposure for minimum of 5 years.

Table 16. Radiographic Abnormalities by Smoking Status

	Smokers			Ex-smokers			Non-smokers		
	Total	Prevalence	p*	Total	Prevalence	p*	Total	Prevalence	p*
Rounded Small Opacities									
Cement Workers	666	7 (1.1%)	0 01	382	4 (1.0%)	0.46	414	1 (0.2%)	1.00
Control Group B	701	0 (0.0%)		168	0 (0.0%)		523	2 (0.4%)	
Irregular Small Opacities									
Cement Workers	665	12 (1.8%)	0.002	383	3 (0.8%)	0.67	414	0 (0.0%)	1.00
Control Group B	701	1 (0.1%)		168	0 (0.0%)		519	0 (0.0%)	
Pleural Abnormalities									
Cement Workers	664	19 (2.9%)	0.0001	383	3 (0.8%)	0.67	412	2 (0.5%)	0.82
Control Group B	702	2 (0.3%)		168	0 (0.0%)		523	1 (0.2%)	

* p value for testing the hypothesis that the cement workers have the same prevalence as control group B, using the Fisher's exact test.

Table 17. Ventilatory Function

	Crude Means		Adjusted Means*		
	Cement Workers	Control Group A	Cement Workers	Control Group A	p+
FVC (L)	4.87	4.88	4.47	4.45	0.76
FEV_1 (L)	3.76	3.85	3.51	3.51	0.93
PF (L/S)	9.47	9.52	8.87	8.85	0.94
FEF_{50} (L/S)	4.59	4.76	4.60	4.57	0.77
FEF_{75} (L/S)	1.49	1.68	1.49	1.51	0.74

* Adjusted for age, sex, race, height, and smoking, with plant nested within group.

+ p value for testing the hypothesis that the cement workers have the same adjusted mean as control group A, using the F test.

Table 18. Significant Exposure - Response Relationships in the Cement Workers

A. Chronic Phlegm*

	Previous Job Tenure, yr				
	0	5	10	20	30
OR_{adj}:	1.00	1.12	1.26	1.60	2.02

Equation: $OR_{adj}=e^{0.0020(PJT)}$

B. Wheezing*

		Previous Job Tenure, yr				
		0	5	10	20	30
Current Respirable Dust, mg/m^3						
0	OR_{adj}:	1.00	1.13	1.27	1.62	2.06
1		1.13	1.27	1.44	1.83	2.33
3		1.44	1.62	1.83	2.33	2.96
5		1.83	2.06	2.33	2.96	3.77

Equation: $OR_{adj}=e^{0.1205(RD) + 0.0020(PJT)}$

C. Pleural Abnormalities+

		Previous Job Tenure, yr								
		0			5			10		
		Current Total Dust (mg/m^3)								
Current Job Tenure, yr		0	10	20	0	10	20	0	10	20
0	OR_{adj}:	1.00	2.27	5.14	1.60	3.63	8.24	2.56	5.82	13.19
5		2.16	2.84	3.73	3.46	4.54	5.97	5.54	7.28	9.56
10		4.66	3.55	2.70	7.47	5.68	4.32	11.96	9.10	6.92

Equation: $OR_{adj}=e^{0.0819(TD) + 0.0128(CJT) + 0.0078(PJT) - 0.0009(D*CJT)}$

D. Peak Flow+

Dose Variable	Regression Coefficient
Respirable dust	$-103.2\ ml \cdot sec^{-1}/mg \cdot m^{-3}$

* $p \leq 0.05$.
\+ $p \leq 0.01$.

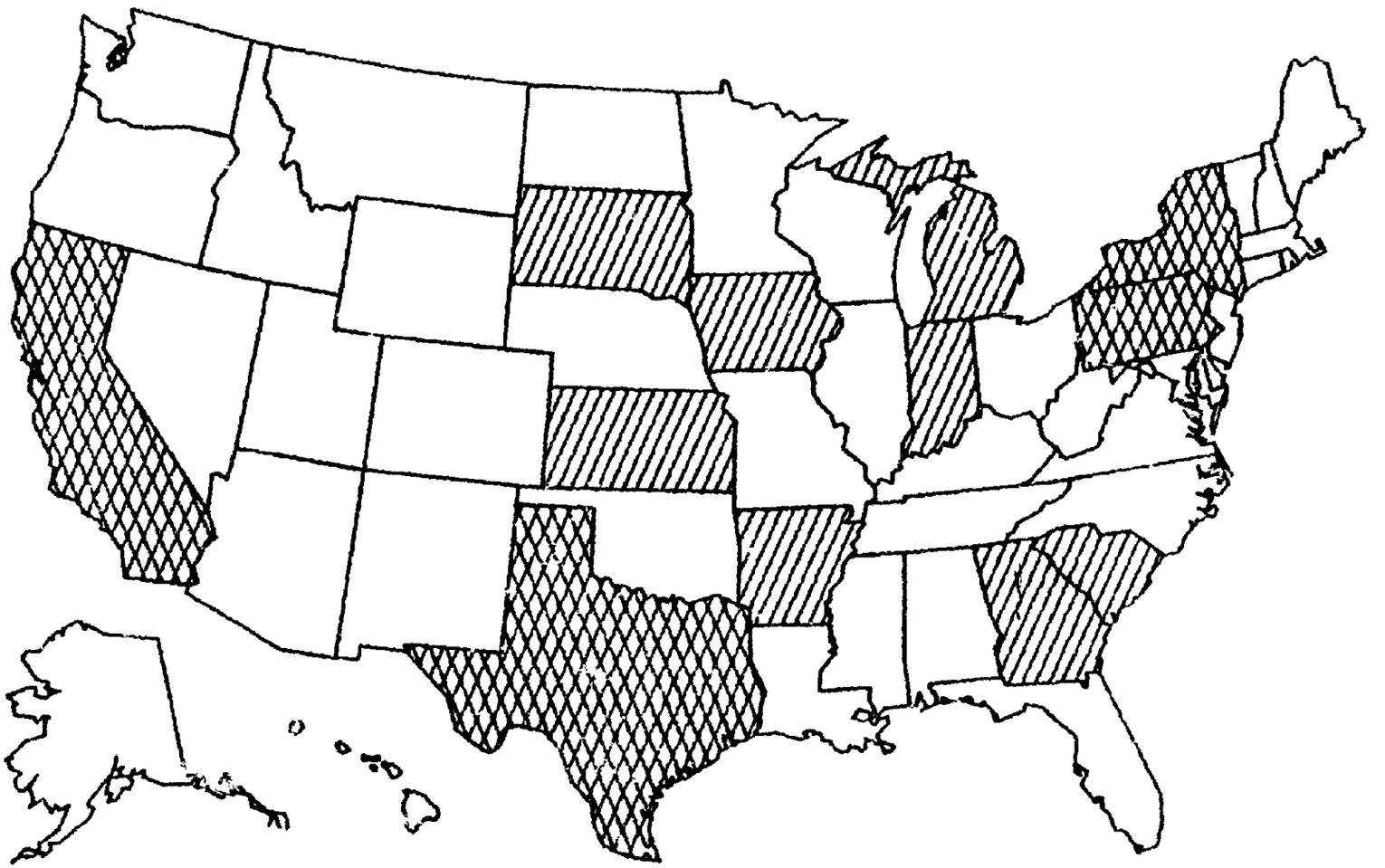
Table 19. Comparison of Results For White Males

	Present Study	Kalacic[9]
N	1724	847
Crude Prevalence of Symptoms, %		
Chronic Cough	17.4	41.6
Chronic Phlegm	19.7	37.8
Chronic Bronchitis with Exacerbations*	3.7	1.6
Chronic Bronchitis with Obstruction	4.9	11.2
Dyspnea	5.5	8.5
Wheeze	9.3	7.4
Asthma	8.8	3.0
Age, yr+	41.1 (9.9)	39.9 (6.8)
Smoking, %**		
Non-smokers	21.8	23.3
Ex-smokers	30.7	18.3
Light Smokers	7.0	10.5
Moderate Smokers	20.4	34 2
Heavy Smokers	20.0	13.7

* For this comparison, the present study definition was changed to require phlegm production for the entire day.
\+ Mean (SD).
** Definitions conform to Reference 9.

FIGURE 1

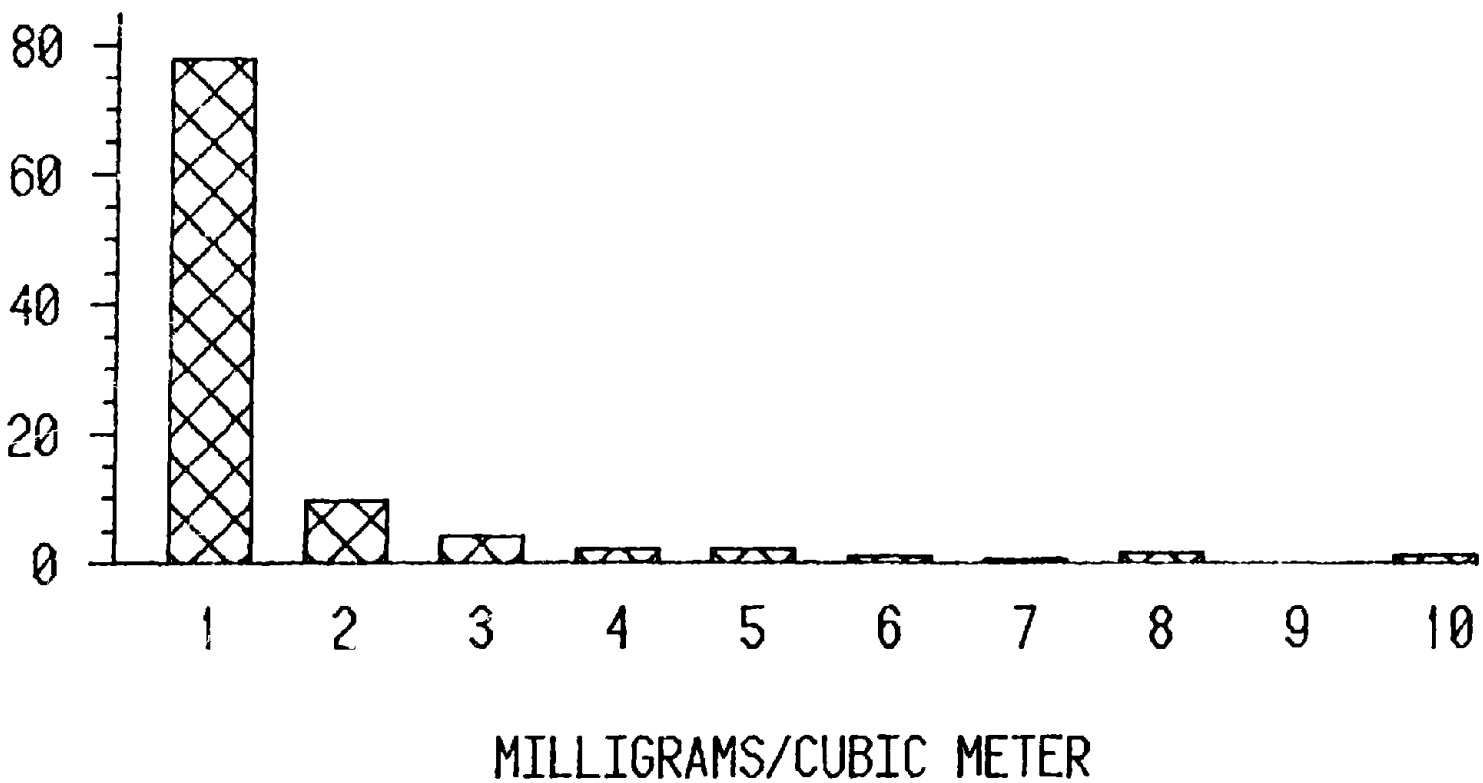
LOCATION OF CEMENT PLANTS STUDIED



STATES WITH ONE PLANT TWO PLANTS

FIGURE 2

DISTRIBUTION OF PERSONAL RESPIRABLE DUST SAMPLES (N=1011)

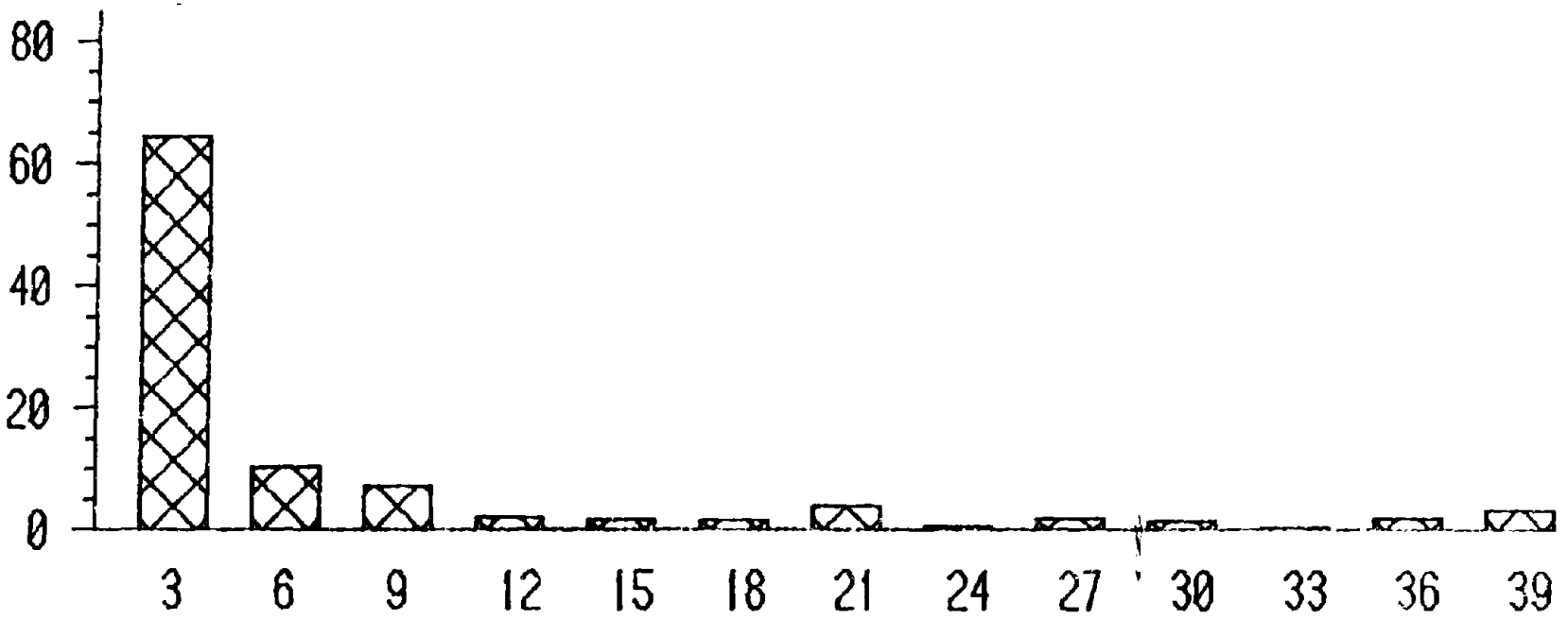


77.8 87.6 91.9 93.9 95.8 96.8 97.4 98.4 98.4 100

CUMULATIVE PERCENT

FIGURE 3

DISTRIBUTION OF PERSONAL TOTAL DUST SAMPLES (N=211)



64.5 74.9 82.0 83.9 85.3 86.7 90.5 91.0 92.9 94.3 94.8 96.7 100

CUMULATIVE PERCENT

FIGURE 4

DISTRIBUTION OF INDIVIDUAL RESPIRABLE DUST LEVELS (N=2298)

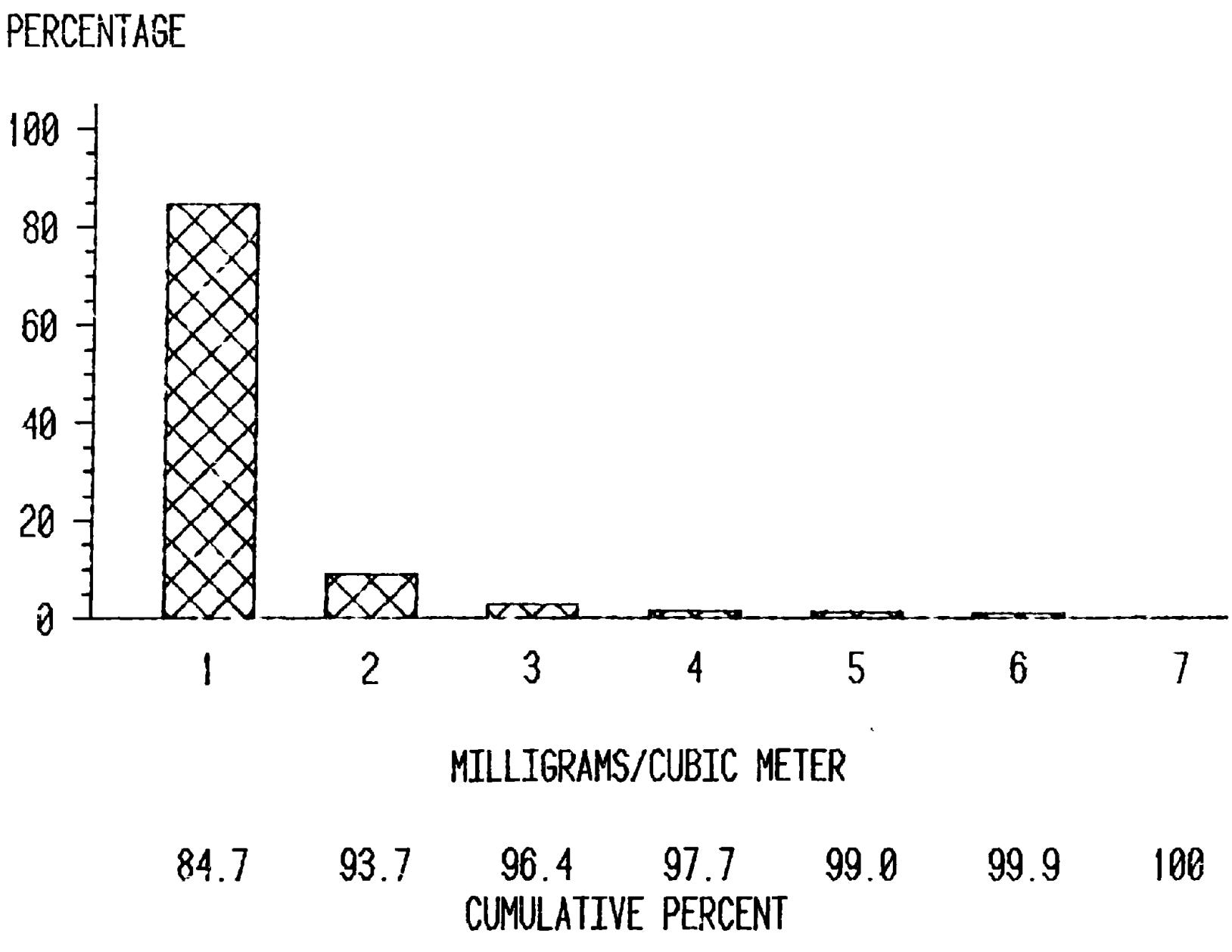
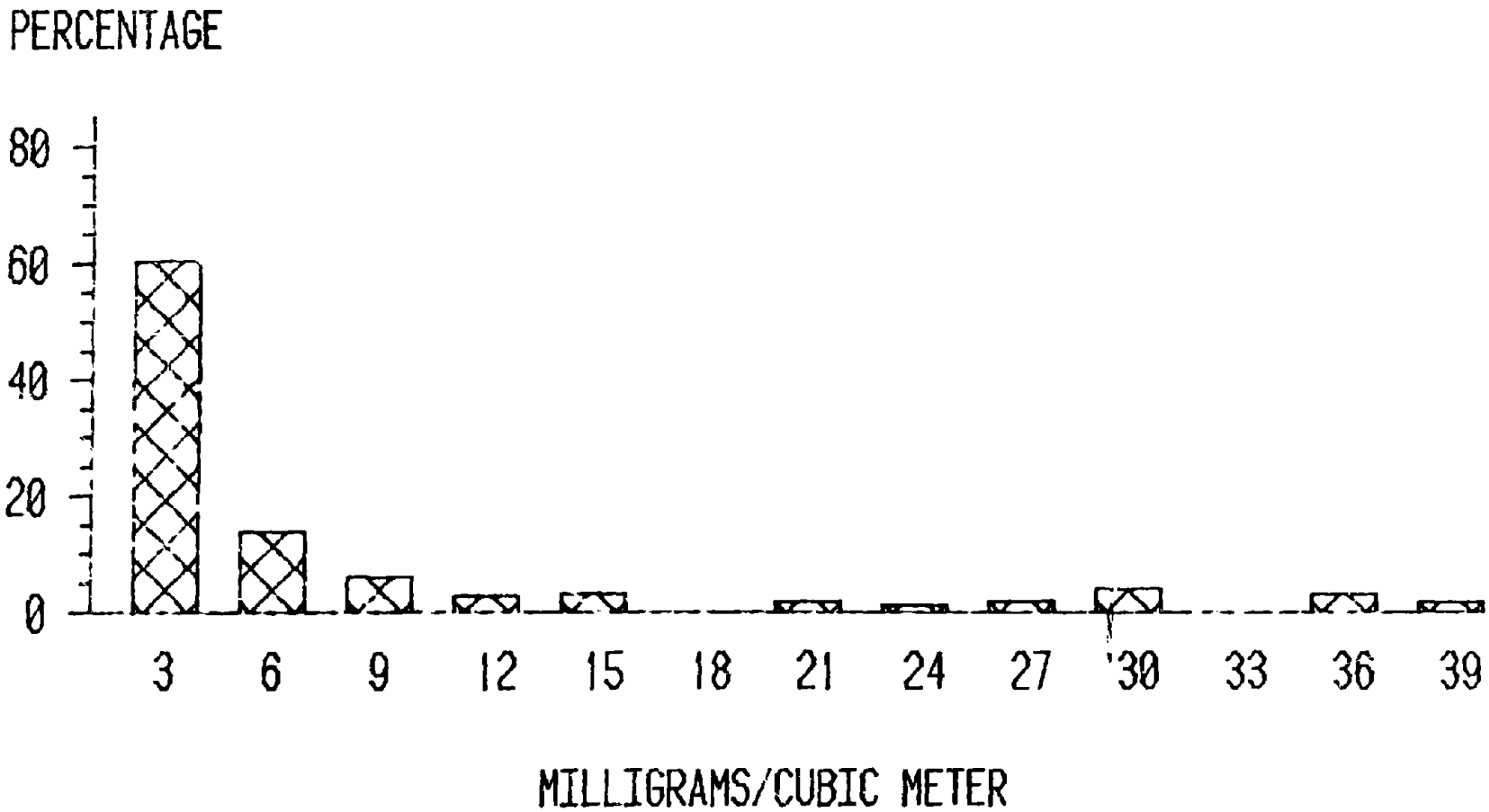


FIGURE 5

DISTRIBUTION OF INDIVIDUAL TOTAL DUST LEVELS (N=1040)



60.6 74.4 80.4 83.3 86.3 86.3 88.1 89.3 91.1 95.0 95.1 98.2 100

CUMULATIVE PERCENT

FIGURE 6

DISTRIBUTION OF CEMENT WORKER TENURE (N=2736)