Airflow limitation and the prevalence of chronic bronchitis amongst cement workers in South Africa

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Abstract

The study set out to measure the effects of cement dust on non-smoking workers. The research took the form of a cross sectional design in order to establish how both the level and the duration of exposure to cement dust affects the health of cement workers.

Quota sampling was done to ensure that the sample represented workers from high, medium and low levels of exposure to cement dust with varying duration of exposure. Data collection took place in two phases. The first phase established the cause and the second phase measured the health outcomes.

Cement dust levels were well within the prescribed level of 5 mg/m³. Airflow limitation was found, to a mild degree, in 13% of respondents, chronic bronchitis in 2,3% and no radiological changes due to cement dust exposure were evident.

Reliability and validity of the instruments used and ethical considerations were emphasised throughout the study.

1. Introduction

There are several types of cement blends, each suitable for a different application. This study is concerned with workers exposed to Portland cement, which is a hydraulic binder that reacts with water and then rapidly hardens. It is used in building construction and civil engineering[1].

The principal raw materials in Portland cement manufacturing are limestone and clay or shale that are crushed and burned together in a fired kiln, forming clinker. The main constituents of clinker are calcium oxide, silica, alumina and iron oxide. The clinker is cooled and then ground and gypsum is added to slow down the setting of the cement[1].

Cement dust is listed in the Hazardous Chemical Regulations[3] of the Occupational Health and Safety Act[4] with the recommended occupational exposure limit of respirable dust of 5 mg/m³.

In the literature search a total of 65 studies on the health effects of Portland cement as well as three occupational medicine textbooks were found to be generally in agreement that cement dust does cause respiratory symptoms, chronic bronchitis and airflow limitation. In respect of cancer and radiological changes caused by exposure to cement dust there was however, contradiction.

Stuart Levy in Zenz, Dickerson and Horvath (1994) described the effects of cement dust on the lungs of cement workers who bagged the finished product and therefore had the highest exposure levels in the past (before bagging was automated). He stated that the chest X-rays of ‘baggers’ were reported to be normal but that the pulmonary function tests revealed obstructive impairment which is accentuated by cigarette smoking[2]. To exclude the possible confounding effect of smoking on the respiratory system, this study was limited to non-smokers.

Subjective observation indicates that the level of cement dust in the work area and the period of exposure are critical factors in causing respiratory symptoms in susceptible workers. Well-designed research studies and quality medical surveillance and environmental monitoring programmes are required to reach a final conclusion on the relationship between cement dust and its effects on the respiratory system.

The following research objectives were set to achieve the purpose of the study:

- ➢ description of respiratory symptoms and the extent to which airflow limitation and/or chronic bronchitis is found in workers exposed to cement dust,
- ➢ detection of radiological changes in the lungs attributable to cement dust exposure,
- ➢ relation of the measured health outcomes to cement dust exposure levels,
- ➢ establishment as to whether the degree of

TABLE 1. AVERAGE ENVIRONMENTAL CEMENT DUST LEVELS MEASURED IN 2002.

Exposure level	Work area	Personal samplers			Strategic samplers		
		Number of samples	Mean mg/m^3	SD	Number of samples	Mean mg/m^3	SD
High							
3–4,9 mg/m^3	Cement mill	54	1,8	1,1	12	2,2	2,0
	Packing plant	36	2,1	1,8	12	2,3	2,0
	Maintenance crew – chokes, break-downs	30	3,4	4,4	4	8,4	2,2
Medium							
1,5–2,9 mg/m^3	Kiln	28	1,4	1,3	12	1,8	1,1
	Dispatch	24	1,6	1,4	12	2,0	1,4
	Laboratory	12	0,8	0,8	8	0,6	2,0
Low	Administration	0	–	–	4	0,4	0,8
<1,5 mg/m^3	Managers – sporadic exposure	6	1,5	2,2			

adverse effects increases with the duration of exposure to cement dust.

2. METHODOLOGY

A cross sectional study using quantitative, descriptive and contextual strategies was chosen to allow for follow-up of the cause-and-effect relationship[5].

Data were collected in two simultaneous phases:

In the first phase the cause was established. Thus the cement dust levels were measured in order that the measured health outcomes determined in phase two, could be related to the cement dust exposure level and duration of exposure of each respondent. Records of environmental monitoring of levels of cement dust and its compounds, in the different work areas, over the previous ten years, were studied. The monitoring was done by occupational hygienists who are accredited by the Department of Labour as required in the Occupational Health and Safety Act[3].

The variations of cement dust levels due to increased production levels, cement spills, or the wind factor on certain days were taken into account. These readings are taken annually unless there are unusual circumstances or deviations from the average, when it is done more frequently. Equipment is calibrated according to South African Bureau of Standards (SABS) standards. The records showed a steady decline in the dust levels at the different sites over the years, due to increasingly effective dust control measures.

In addition, the ongoing personal sampling of respirable dust as experienced by workers in dust areas, was also analysed. This is done according to set standards and the same occupational hygiene laboratories evaluate the sampler filters. The risk management departments and the company central laboratory services recorded these results for the past ten years or more.

The historical job titles (as used by the

TABLE 2. THE ORIGINAL SAMPLE ACCORDING TO CEMENT DUST LEVELS IN THE DIFFERENT AREAS (N = 222)

Level of cement dust	Work areas	Respondents
High >5 mg/m^3	Packing plant Cement mill, Silo Maintenance crew	74
Medium 2 – 4,9 mg/m^3	Kiln & clinker Dispatch Laboratory	76
Low <2 mg/m^3	Administrative Sales staff	72 n = 222

TABLE 3. THE SAMPLE ACCORDING TO CUMULATIVE CEMENT DUST EXPOSURE INTENSITY (N=222).

Respondents n=222	Cumulative Exposure Intensity (CEI)		
	Range	Mean	SD
109 (49%)	20–233	71,15	9,9
71 (32%)	5,0–19,9	13,39	8,7
42 (19%)	2,25–4,9	3,86	3,3
222 (100%)	2,25–233	39,94	

TABLE 4. THE SAMPLE ACCORDING TO DURATION OF EXPOSURE (N = 222).

Duration of exposure	Respondents	Range	Mean	SD
>10 years	80 (36,03%)	10–32 years	17,4	5,1
5–10 years	70 (31,53%)	5–10 years	8,2	1,7
<5 years	72 (32,43%)	1–4,8 years	4,0	0,77
	n = 222			

respondents) were listed with the help of the Human Resources department in this phase. These titles, as used to describe the respondent's job history in the questionnaire, were linked to the applicable cement dust levels by the researcher.

See Table 1 for the average environmental cement dust levels measured in 2002.

The second phase focused on the individual. This phase involved the medical examination, lung function testing and the administration of a questionnaire to the respondents. The second phase addressed the objectives that required:

➢ accurate measurement of airflow in the lungs of respondents,
➢ description of respiratory symptoms experienced by respondents,
➢ radiological findings in the lungs, and
➢ medical and occupational exposure history of each respondent. (This was linked to the current and historical cement dust levels established in the first phase.)

In terms of the company risk management policy and the Occupational Health and Safety Act[3] these workers undergo periodic medical examinations. The annual medical surveillance programme is planned well in advance to ensure that each worker does have a full medical examination at least once in 12 months.

The target population included all non-smokers at four cement plants in South Africa (n = 307). A non-smoker has never smoked or has stopped smoking more than five years ago and never smoked more than five cigarettes a day.

The levels of cement dust varies according to the different production processes in a cement plant and non-smoking workers from high, medium and low levels of cement dust exposure in the different departments, were given the opportunity to take part in the study. Traditionally, these workers are divided between semi-skilled line workers, artisans, professional persons and administrative staff.

The established programme allowed for quota sampling while avoiding bias with regard to the selection of the respondents. Quota sampling was used to ensure equal representation from the different levels of exposure to respirable cement dust. Employees, in sequence from the existing annual programme at each plant, were invited to take part in the study. The sample population (n = 222) was stratified into one of three exposure groups according to the dust levels in their current and previous work areas:

➢ Workers with exposure to high levels of cement dust (>5 mg/m^3) as in the packing plants (packer operators), production department (machine operators and attendants) and maintenance crew and labourers in both areas. (n = 74)

➢ Workers with exposure to medium levels of cement dust (2 – 4,9 mg/m^3) as in the kiln areas (burners and cleaners) and the pulverising area in laboratories (laboratory technicians). (n = 76)

➢ Workers with low levels of exposure to cement dust (<2 mg/m^3) as in the administration personnel in the office block on site. (n = 72)

Table 2 depicts the sample according to cement dust levels.

Specially trained occupational health practitioners administered a questionnaire on medical, occupational and respiratory symptom history (based on the American Thoracic Society (ATS) respiratory questionnaire[6] and collected data from the results of physical examinations, spirometry assessments and chest X-ray reports. The cement dust levels of exposure, the period of exposure in years and the history of previous occupations

TABLE 5. LUNG FUNCTION RESTRICTION AND APPLICABLE CEI (N = 9).

Age in years	Mean cement dust level in each job 1	2	3	4	5	Duration in each job 1	2	3	4	5	Cumulative Exposure Intensity (CEI)
30	1,8	1,2				5	2				10,5
32	3,5	2,0				5	2				24,5
37	4,7	3,8				5	5				47,0
31	2,0					3					6,0
28	1,8	1,6				5	2				12,2
32	1,8					4					7,2
33	4,8	3,8				4	3				33,6
44	5,4	4,6				12	5				87,8
24	3,0					2					6,0

Mean age = 32,33 years CEI range = 2,4–87,8 Mean CEI = 25,44 (SD 30,3)

TABLE 6. AIRFLOW OBSTRUCTION AND THE CEI OF EACH RESPONDENT (N = 9).

Age in years	Mean cement dust level (mg/m³) Job 1	2	3	Duration in each job 1	2	3	Cumulative Exposure Intensity (CEI)
30	4,0			2			8,00
48	3,0	2,6		4	9		35,40
47	5,0	5,0		8	17		12,50
33	0,5	0,4		3	2		2,25
49	8,4	4,9	3,4	15	9	4	183,70
51	1,0	0,6		20	6		23,60
29	2,5	2,0		4	1		12,00
30	4,2			2			8,40
49	6,4	3,2		10	3		73,60

Mean age = 40,6 years CEI range = 2,25–183,7 Mean CEI = 52,43 (SD 7,8)

TABLE 7. DISTRIBUTION OF CHRONIC BRONCHITIS AMONG NON SMOKING CEMENT WORKERS, AND CEI (N = 5).

Resp. No.	Exposure years Job 1	2	3	Cement dust level mg/m³ Job 1	2	3	CEI
11	3	4		3,2	2,2		18,4
16	15	4		2,4	1,0		4,0
55	3			0,8			2,4
158	4	3		2,0	1,0		11,0
217	10	5	5	7,8	3,2	1,6	102,0

CEI range = 2,4–102 Mean CEI = 27,56 (SD 39,2)

was collected from the medical file of each respondent and from risk management records and the human resource department.

The company physicians at the factories performed annual physical examinations of all exposed workers as per specific instruction. Trained operators performed annual lung function tests according to the ATS standards (1994). The Forced Expiratory Volume in one second (FEV1), the Forced Vital Capacity (FVC) and the Forced Expiratory Volume in one second and Forced Expiratory Volume ratio (FEV1/FVC) was considered the most important values for the study. Chest X-rays were taken when due – usually once in three years – and read by local radiologists before being forwarded to the National Centre of Occupational Health (NCOH) for a specialist radiologist's report. The researcher encoded a copy of the specialist's report for each respondent.

It was an advantage to use the company Occupational Health Nurse, as a fieldworker. She knows the workers and the company routine. As a fieldworker, each received special training to ensure that she remained impartial and did not allow her knowledge of worker health status or occupational exposure to influence the outcome of the questionnaire or specific tests.

The fieldworkers were trained on the correct approach and techniques such as the prompt words to use when administering the questionnaire. Each Occupational Health Nurse also received specific spirometry training from specialists at the NCOH and the Lung Function Laboratory at the Johannesburg General Hospital. It was explained that the responsible practitioner in charge of the spirometry programme should be committed to zero defects in lung function tests and the quality of her programme. This includes equipment calibration and maintenance and infection control.

Medical centres with the necessary equipment are on the sites as well as existing medical and environmental records. All equipment used was calibrated according to standards of the South African Bureau of Standards (SABS). Reliability of the measuring instruments was tested. A minimum of variance in interpretation of the questions by the respondent and of his answer by the Occupational Health Nurse was achieved.

The cumulative exposure intensity (CEI) was calculated for each respondent, for each cement dust level exposed to and the duration of exposure to that level, in his service period in the cement industry. The average CEI was 39,94 (See Table 3).

All respondents' questionnaires, spirograms and chest X-ray reports were evaluated for accuracy and completeness by the researcher before the data was entered into the Epi Info 6 Version 6.04b computer program for systematic organisation and synthesis and analysis. Cronbach's alpha reliability index for internal consistency of the questionnaire was applied as a measure of accuracy of the results.

Throughout this research project ethical principles of honesty, respect for human rights and for scientific objectivity were upheld.

3. Results

In setting out to relate the measured health outcomes to cement dust exposure levels and to establish whether the degree of adverse effects increases with the duration of exposure to cement dust it was found that:

- The mean cumulative exposure intensity (CEI) for the total sample (n=222) of cement workers was 39,80 within a range of 2,25 to 233. Refer Table 3.
- Airflow restriction was evident in nine (6,52%) spirograms (n = 138) with the respondents all showing a mild degree of limitation. The mean CEI was 25,44 within a range of 2,4 to 87,8. The average age of these respondents was 32,33 years – see Table 5.
- Nine respondents (6,52%) showed a mild degree of airflow obstruction. These respondents were older – mean age 40,6 years – with a mean CEI of 52,43. The CEI range was from 2,25 to 183,7. This was the strongest link of health effects to cement dust exposure in this study. (Refer Table 6).
- Five (2,3%) respondents were found to have chronic bronchitis. Within the range of 2,4 to 102, the mean CEI was calculated to be 27,56 – indicating lower exposure and therefore not a strong link to cement dust exposure. (Refer Table 7).
- No radiological changes due to cement dust exposure were reported.

Results can only be generalised for non-smokers in the cement industry and for those who work with dry cement in the construction industry. Further research is required to assess the effect of cement dust inhalation among smokers and also to assess the prevalence of other respiratory symptoms.

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