SH@W Safety and Health at Work www.e-shaw.org

Saf Health Work 2011;2:243-9 | http://dx.doi.org/10.5491/SHAW.2011.2.3.243

pISSN : 2093-7911
eISSN : 2093-7997

Original Article

Cancer Mortality and Incidence in Cement Industry Workers in Korea

Dong-Hee KOH, Tae-Woo KIM, Seung Hee JANG and Hyang-Woo RYU

Occupational Safety and Health Research Institute, Korea Occupational Safety and Health Agency, Incheon, Korea

Objectives: Cement contains hexavalent chromium, which is a human carcinogen. However, its effect on cancer seems inconclusive in epidemiologic studies. The aim of this retrospective cohort study was to elucidate the association between dust exposure in the cement industry and cancer occurrence.

Methods: The cohorts consisted of male workers in 6 Portland cement factories in Korea. Study subjects were classified into five groups by job: quarry, production, maintenance, laboratory, and office work. Cancer mortality and incidence in workers were observed from 1992 to 2007 and 1997-2005, respectively. Standardized mortality ratios and standardized incidence ratios were calculated according to the five job classifications.

Results: There was an increased standardized incidence ratio for stomach cancer of 1.56 (27/17.36, 95% confidence interval: 1.02-2.26) in production workers. The standardized mortality ratio for lung cancer increased in production workers. However, was not statistically significant.

Conclusion: Our result suggests a potential association between cement exposure and stomach cancer. Hexavalent chromium contained in cement might be a causative carcinogen.

Key Words: Cement, Cancer, Dust, Stomach cancer, Limestone

Introduction

In 1824, Joseph Aspdin calcined a mixture of limestone and clay in a furnace, and this is the origin of current Portland cement [1]. Since then, Portland cement has been used widely, and its health effects have become an important issue both for workers and the environment. In addition to cement industry workers who make cement from raw materials, many construction workers are also exposed to cement dust, and even people living in houses built with cement might be exposed to cement dust.

Received: February 15, 2011, **Revised:** May 13, 2011
Accepted: May 13, 2011
Correspondence to: Dong-Hee KOH
Occupational Safety and Health Research Institute
Korea Safety and Health Research Institute
478, Munemi-ro, Bupyeong-gu, Incheon 403-711, Korea
Tel: +82-32-510-0833, **Fax:** +82-32-518-0862
E-mail: koh.donghee@gmail.com

Dermatitis due to contact with cement is a well-known occupational skin disease, and the main cause of skin lesions is hexavalent chromium (Cr^{6+}). Decreased lung function and increased chronic obstructive pulmonary disease prevalence have also been reported due to cement dust exposure [2,3]. Several studies have been conducted evaluating the carcinogenic effects of cement, but the results have been inconclusive, even though some cancers, such as lung and gastrointestinal cancers, have a suspected association with cement dust exposure [4-8].

In the middle of the baking process for cement in kilns, Cr^{3+} is oxidized to Cr^{6+}, but after that process the content of Cr^{6+} decreases slowly over time. The International Agency for Research on Cancer (IARC) classified Cr^{6+} as a definite carcinogen for humans (Group I), targeting the lung and sinonasal areas [9]. In spite of containing Cr^{6+}, the carcinogenic effect of cement dust exposure has not been fully elucidated in human subjects. Hence, this study investigated the potential relationship between exposure in the cement industry and the development of various cancers.

Materials and Methods

Cohort definition

There have been seven major companies manufacturing Portland cement in Korea since the 1950s. Two of them have two factories each, therefore a total of nine Portland cement manufacturing factories were running at the time of this study. There was no major difference in the manufacturing process among these factories.

Lists of worker information were assembled for each factory, and included employment date, retirement date, job type, and resident registration number. After collecting the lists, all databases were evaluated for completeness, resulting in the exclusion of databases from three companies. Female workers were excluded from the databases, because the number of female workers was too small, and most of them occupied office positions. Thus, the retrospective cohorts consisted of only male workers who worked at least one day during 1992-2007 (cancer mortality cohort) at one of four Portland cement manufacturing companies or 1988-2005 (cancer incidence cohort) at one of six Portland cement manufacturing factories.

Job group classification

The process of cement manufacturing consists of quarry, rawmill, kiln, cement mill, and packing/shipment. Quarries are located adjacent to manufacturing factories, and mined limestone is crushed and then transferred to the rawmill process by conveyor belt. In the rawmill process, limestone is mixed with small amounts of other raw materials, such as silica and iron ore, and then ground into powder. This powder is transferred to the kiln and baked with a burner using coal, during which the temperature of the kiln exceeds 1,400°C. During this process, free crystalline silica is usually melted and fused with $CaCO_3$ and other raw materials. The final output of the kiln process is called clinker, and it is transferred to the cement mill and mixed with a small amount of gypsum. Then it is ground into a powder again as commercial cement. During the quarry process, workers are mainly exposed to limestone dust; however, during the kiln-to-packing process, workers are exposed to cement dust containing Cr^{6+}.

The subjects' jobs were classified into five groups by occupational type: quarry, production, maintenance, laboratory, and office. Quarry workers perform drilling and blasting of stone or run crushers. Production workers operate production processes or pack/ship cement. Maintenance workers repair and maintain production equipment, and laboratory workers usually perform chemical content analysis of cement and byproducts. Job histories were not available except for workers' last departments. Therefore, the last job was used as a proxy for exposure. Cancer risks were evaluated according those five job type classifications.

Statistical analysis

Standardized mortality ratios (SMRs) and standardized incidence ratios (SIRs) for cancers in cement industry workers were calculated. Cancer mortality and incidence were identified by the national death registry during 1992-2007 and the cancer registry during 1988-2005. The entry point of the cohort was Jan 1, 1992 for cancer mortality and Jan 1, 1988 for cancer incidence, or the date the worker began working at his company if the worker entered after those years. The exit point of the mortality cohort was the date of death, and that of the cancer incidence cohort was the date of death or cancer diagnosis. Overall, for the mortality cohort, the cases were observed and person-years were enumerated from Jan 1, 1992 to Dec 31, 2007. While the cancer incidence cases were identified from 1988 to 2005, however, for the cancer incidence cohort, cases and person-years were enumerated only for 1997-2005, because the national cancer incidence rates were not available in early study periods due to low cancer registration rates.

Case/person-year tabulation for the mortality cohort was conducted using the Life Table Analysis System (LTAS.NET) with 5-year intervals of age and 4 calendar periods: 1992-1996/1997-2001/2002-2006/2007 [10]. Korean male cancer mortality rates in 1994, 1999, 2004, and 2007 were used as reference rates. For the cancer incidence cohort, case/person-year tabulation was performed with 5-year intervals of age using STATA, with the Korean male cancer incidence rate in 2003 used as a reference rate. Cancer mortality rates and incidence rates of each cohort were compared with the national mortality and national cancer incidence rates using indirect standardization of the rates. Exact Poisson confidence interval (CI)s were also calculated for SIRs using SAS macro [11].

Classification of cancer was performed following US NIOSH-119 (US National Institute for Occupational Safety and Health) occupational cancer classification [12]. Deaths were identified by the Statistics Korea (KOSTAT), a registry estimated to cover more than 95% of all deaths. KOSTAT records provide dates and causes of death based on tenth revision of International Classification of Diseases (ICD-10). Cancer incidences were identified by the Central Registry of Cancer in Korea. Summary results of SMRs and SIRs for each type of cancer after standardization for age and calendar period were calculated.

Results

The number of subjects for the mortality cohort and cancer incidence cohort were 5,146 and 5,596, respectively. The most frequent job group was production, which comprised approximately 40% of all jobs. The mean age and work duration of workers were 35.3 years for the mortality cohort and 33.1 years for the cancer incidence cohort (Table 1).

All cancer mortality rates for all workers were insignificantly lower than reference values from the Korean adult male population. There was no significantly-increased cancer mortality according to the five job classifications (quarry/production/maintenance/laboratory/office) (Table 2).

All cancer incidences for all workers slightly increased, but were statistically insignificant. The stomach cancer incidence was significantly increased in production workers (SIR 1.56, 95% CI: 1.02-2.26) according to the five job classifications (Table 3).

Discussion

In this retrospective study, we estimated cancer mortality and incidence of workers in the cement industry. Cement industry workers are exposed to various dusts, such as limestone, cement, coal, silica, and gypsum. Among them, cement and limestone dust are the main components of exposed dusts.

Table 1. General characteristics of study subjects

Type of cohort	Job classifications	No. of workers		Age *(years)	
		No.	%	Mean	SD
Cancer mortality cohort	Quarry	500	9.7	38.2	8.4
	Production	2,029	39.4	36.2	9.3
	Maintenance	894	17.4	33.4	9.9
	Laboratory	345	6.7	31.3	8.4
	Office	1,378	26.8	35.1	10.0
	Total	5,146	100	35.3	9.6
Cancer incidence cohort	Quarry	528	9.4	35.6	8.04
	Production	2,150	38.4	33.9	8.6
	Maintenance	928	16.6	31.7	9.1
	Laboratory	356	6.4	29.3	7.4
	Office	1,634	29.2	33.0	9.6
	Total	5,596	100	33.1	9.0

No: number, SD: standard deviation.
*At the time of cohort entry.

Manufacturing cement can be divided into two major parts: quarrying of the limestone and cement production. Characteristics of exposed hazards are different according to these manufacturing processes. During the mining and milling of limestone, workers are exposed to airborne limestone dust containing a variety of minerals, whereas during the kiln-to-packing process, workers are exposed to cement dust containing Cr^{6+} [13].

Limestone ore can contain various minerals besides calcium carbonate, which is the main component. In a study of US limestone quarries, crystalline silica, which is known as a potent lung carcinogen, was detected in all nine quarries. Also, the mean α-quartz content was 11% and the respirable α-quartz exposure had a geometric mean of 0.04 mg/m^3 (with a geometric standard deviation of 1.88 mg/m^3) [14,15]. In addition to crystalline silica exposure, exposure measurements in Finnish limestone and dolomite mines showed varying concentrations of quartz and mineral fibers, such as tremolite asbestos and wallastonite [13]. The contents of quartz and mineral fiber depend on the location of the quarry. During the kiln-baking process, Cr^{6+} is formed by oxidation. Thus, after this process, cement contains Cr^{6+}. Portland cement is in powder form with an aerodynamic diameter ranging from 0.05 to 5 μm. This size is within the range of sizes of respirable particles which can reach the alveoli of the lungs [16]. There have been reports of occupational exposure to cement dust in men leading to increased frequency of chromosomal aberrations [17,18]. The authors of these studies suggested Cr^{6+}, and less likely aluminum and silica, could be causing chromosomal aberration and sister chromatid exchange. In addition to these carcinogens, workers or residents near cement factories could be exposed to atmospheric emissions of various chemicals, such as NO_2, SO_2, CO_2, CO, dioxin, polycyclic aromatic hydrocarbon (PAH)s, and metals [16].

Thus, it has long been suspected that workers exposed to cement dust would exhibit increased risks of lung cancer, but the relationships have not been determined. One cohort study reported an increased risk of lung cancer among cement workers [5], and in another study of masons handling cement, a high mortality rate of lung cancer (SMR 3.14, 95% CI: 1.43-5.95) was reported [19]. Laryngeal cancers also have been reported in individuals with exposure to cement dust (odds ratio [OR] 2.22, 95% CI: 1.02-4.84) [20]. Stomach cancer and colorectal cancers were reported to be associated with Portland cement production [6,8]. However, the results of studies showing relevant cancer risks have been inconsistent in many epidemiological studies.

For stomach cancer, in a case-referent study, there was an

Table 2. SMRs for all workers by job classification

	Quarry (PY = 7,451)			Production (PY = 29,486)			Maintenance (PY = 12,611)			Laboratory (PY = 4,919)			Office (PY = 19,653)			All subjects (PY = 74,123)		
	Obs	SMR	95% CI	Obs	SMR	95% CI	Obs	SMR	95% CI	Obs	SMR	95% CI	Obs	SMR	95% CI	Obs	SMR	95% CI
All cancer	15	1.02	0.57-1.68	41	0.76	0.56-1.06	16	0.84	0.48-1.37	5	1.03	0.33-2.39	26	0.79	0.51-1.15	103	0.83	0.68-1.01
Digestive organs	15	1.53	0.85-2.52	22	0.63	0.39-0.95	13	1.04	0.55-1.78	3	0.91	0.19-2.66	17	0.79	0.46-1.26	70	0.85	0.66-1.08
Esophagus	0	-	-	2	1.18	0.14-4.27	0	-	-	0	-	-	1	0.94	0.02-5.26	3	0.76	0.16-2.21
Stomach	5	1.85	0.60-4.32	5	0.52	0.17-1.21	3	0.85	0.17-2.47	1	1.12	0.03-6.25	5	0.8	0.26-1.88	19	0.83	0.50-1.29
Intestine	1	2.03	0.05-11.31	1	0.57	0.01-3.15	0	-	-	0	-	-	0	-	-	2	0.47	0.06-1.71
Rectum	0	-	-	1	0.61	0.02-3.42	0	-	-	0	-	-	2	1.94	0.23-7.00	3	0.78	0.16-2.27
Liver, bile duct, gall bladder	8	1.60	0.69-3.15	12	0.68	0.35-1.18	9	1.45	0.66-2.76	2	1.15	0.14-4.16	7	0.66	0.27-1.36	38	0.92	0.65-1.26
Pancreas	1	1.60	0.04-8.91	1	0.45	0.01-2.51	1	1.25	0.03-6.98	0	-	-	2	1.44	0.17-5.20	5	0.96	0.31-2.23
Respiratory system	0	-	-	13	1.25	0.66-2.13	1	0.26	0.01-1.45	2	2.38	0.29-8.59	8	1.17	0.51-2.31	24	0.96	0.62-1.44
Lung, bronchus	0	-	0-1.38	13	1.36	0.72-2.33	1	0.28	0.01-1.59	2	2.60	0.32-9.41	8	1.28	0.55-2.52	24	1.05	0.68-1.57
Urinary organs	0	-	-	1	0.96	0.02-5.36	0	-	-	0	-	-	0	-	-	1	0.40	0.01-2.23
Kidney	0	-	-	1	1.65	0.04-9.22	0	-	-	0	-	-	0	-	-	1	0.70	0.02-3.91
Other and unspecific sites																		
Melanoma	0	-	-	1	10.38	0.26-57.85	0	-	-	0	-	-	0	-	-	1	4.42	0.11-24.65
Brain	0	-	-	3	3.58	0.74-10.47	0	-	-	0	-	-	0	-	-	3	1.50	0.31-4.37
Other and unspecific sites	0	-	-	0	-	-	1	2.78	0.07-15.51	0	-	-	1	1.56	0.04-8.71	2	0.85	0.10-3.07
Lymphatic and hemato-poietic tissues	0	-	-	1	0.41	0.01-2.26	1	1.06	0.03-5.91	0	-	-	0	-	-	2	0.34	0.04-1.22
Non-Hodgkin's lym-phoma	0	-	-	0	-	-	1	2.60	0.07-14.46	0	-	-	0	-	-	1	0.41	0.01-2.26
Multiple myeloma	0	-	-	1	3.51	0.09-19.55	0	-	-	0	-	-	0	-	-	1	1.49	0.04-8.31

SMR: standardized mortality ratio, PY: person-years, Obs: number of observed cases, CI: confidence interval.

Table 3. SIRs for all workers by job classification

	Quarry (PY = 4,455)			Production (PY = 18,207)			Maintenance (PY = 7,740)			Laboratory (PY = 3,070)			Office (PY = 13,759)			All subjects (PY = 47,233)		
	Obs	SIR	95% CI	Obs	SIR	95% CI	Obs	SIR	95% CI	Obs	SIR	95% CI	Obs	SIR	95% CI	Obs	SIR	95% CI
All cancer	19	1.00	0.60-1.56	66	0.93	0.72-1.18	27	1.06	0.70-1.55	8	1.21	0.52-2.38	54	1.09	0.82-1.42	174	1.01	0.87-1.18
Buccal cavity and pharynx	1	2.15	0.05-11.98	1	0.58	0.01-3.20	1	1.60	0.04-8.94	0	-	-	3	2.52	0.52-7.36	6	1.43	0.53-3.12
Tongue	1	14.49	0.37-80.71	0	-	-	0	-	-	0	-	-	0	-	-	1	1.59	0.04-8.87
Other parts of buccal cavity	0	-	-	1	2.15	0.05-11.98	0	-	-	0	-	-	1	3.10	0.08-17.27	2	1.77	0.21-6.41
Pharynx	0	-	-	0	-	-	1	2.83	0.07-15.80	0	-	-	2	2.95	0.36-10.67	3	1.26	0.26-3.67
Digestive organs	13	1.06	0.56-1.81	47	1.03	0.76-1.37	21	1.30	0.81-1.99	2	0.47	0.06-1.70	29	0.93	0.62-1.34	112	1.02	0.84-1.23
Esophagus	0	-	-	2	1.19	0.14-4.29	0	-	-	0	-	-	1	0.86	0.02-4.78	3	0.75	0.15-2.18
Stomach	5	1.07	0.35-2.50	27	1.56	1.02-2.26	9	1.46	0.67-2.76	1	0.62	0.02-3.43	12	1.00	0.52-1.75	54	1.29	0.97-1.69
Intestine	1	0.84	0.02-4.68	3	0.67	0.14-1.97	1	0.63	0.02-3.48	0	-	-	4	1.29	0.35-3.29	9	0.84	0.38-1.59
Rectum	2	1.53	0.19-5.53	6	1.24	0.45-2.69	1	0.58	0.01-3.25	1	2.26	0.06-12.56	5	1.51	0.49-3.53	15	1.29	0.72-2.13
Liver, bile duct, gall bladder	4	0.95	0.26-2.43	8	0.51	0.22-1.01	9	1.68	0.77-3.18	0	-	-	5	0.48	0.16-1.13	26	0.70	0.46-1.03
Pancreas	1	2.13	0.05-11.89	1	0.57	0.01-3.19	1	1.61	0.04-8.98	0	-	-	2	1.62	0.20-5.86	5	1.19	0.38-2.77
Respiratory system	2	0.68	0.08-2.47	9	0.82	0.37-1.56	3	0.76	0.16-2.22	3	3.47	0.72-10.15	10	1.26	0.61-2.32	27	1.01	0.67-1.47
Larynx	0	-	-	1	0.92	0.02-5.12	0	-	-	1	11.73	0.30-65.34	0	-	-	2	0.77	0.09-2.80
Lung, bronchus	2	0.79	0.10-2.85	8	0.84	0.36-1.66	3	0.87	0.18-2.56	2	2.72	0.33-9.84	10	1.45	0.69-2.66	25	1.08	0.70-1.60
Male genital organs	2	4.70	0.57-16.98	4	2.43	0.66-6.22	0	-	-	0	-	-	0	-	-	6	1.44	0.53-3.13
Prostate	2	5.21	0.63-18.84	4	2.72	0.74-6.97	0	-	-	0	-	-	0	-	-	6	1.61	0.59-3.52
Urinary organs	0	-	-	1	0.25	0.01-1.42	0	-	-	2	5.45	0.66-19.70	4	1.46	0.40-3.74	7	0.74	0.30-1.52
Kindey	0	-	-	0	-	-	0	-	-	1	5.20	0.13-28.96	0	-	-	1	0.22	0.01-1.23
Urinary bladder	0	-	-	1	0.49	0.01-2.74	0	-	-	1	5.73	0.15-31.94	4	2.75	0.75-7.03	6	1.21	0.45-2.64
Other and unspecific sites																		
Bone	1	23.13	0.59-128.87	0	-	-	0	-	-	0	-	-	0	-	-	1	2.29	0.06-12.78
Skin (except melanoma)	0	-	-	1	1.34	0.03-7.47	0	-	-	0	-	-	0	-	-	1	0.55	0.01-3.07
Thyroid	0	-	-	0	-	-	1	2.15	0.05-11.99	1	5.87	0.15-32.72	2	2.33	0.28-8.42	4	1.36	0.37-3.47
Lymphatic and hematopoietic tissues	0	-	-	1	0.34	0.01-1.88	1	0.89	0.02-4.97	0	-	-	4	1.88	0.51-4.82	6	0.82	0.30-1.78
Non-Hodgkin's lymphoma	0	-	-	0	-	-	1	1.71	0.04-9.51	0	-	-	3	2.69	0.55-7.86	4	1.03	0.28-2.64
Multiple myeloma	0	-	-	1	2.80	0.07-15.58	0	-	-	0	-	-	1	4.04	0.10-22.50	2	2.32	0.28-8.39

SIR: standardized incidence ratio, PY: person-years, Obs: number of observed cases, CI: confidence interval.

increased OR of 3.2 (95% CI: 1.0-11) for esophageal and stomach cancer [8]. McDowell [6] studied 607 cement plant workers employed in 1939 in England and Wales. In his study, stomach cancer mortality was significantly increased in the overall cohort (SMR = 175), and this was associated with an index of cement plant dust exposure. However, in another study that enrolled workers employed in 23 U.S. non-asbestos cement plants, stomach cancer mortality was not significantly associated with tenure, latency, and year of birth [21]. Furthermore, recent cohort studies of Lithuanian and French cement-producing workers failed to show increased stomach cancer mortality or incidence [5,22].

Our study showed significantly elevated stomach cancer incidence (SIR 1.56, 95% CI: 1.02-2.26) in production workers according to the five job classifications, but there was no concomitant increase of stomach cancer mortality. Stomach cancer is one of the most frequent cancers in Korean men. Therefore, many people undertake endoscopy testing for the early detection of stomach cancer. The prognosis of stomach cancer would be as good as a 90% cure rate if detected in its early stages. Consequently, the number of mortality cases by stomach cancer would be much lower than that of incidence cases that have been shown in our results. Usually workers in the cement industry would have more accessibility to early diagnostic testing than the general male population, because cement companies are supportive to worker health. In terms of this detection bias, because the stomach cancer SIR in office workers was not elevated, we thought that its effect on cancer incidence and mortality might not be influential.

The low stomach cancer SMR might come from the healthy worker effect [23]. However, the discrepancy between stomach cancer mortality and incidence represents limited evidence of the association between cement dust exposure and stomach cancer.

The mechanism of the carcinogenic effect of cement dust to the stomach remains unclear. Some researchers suggested that inhaled dust containing Cr^{6+} moves upward by mucociliary movement from the lung, thus forming sputum, which is then swallowed into the stomach, possibly leading to stomach cancer.

In terms of lung cancer, a recent cohort study revealed significant increases in lung cancer mortality (SMR 1.4, 95% CI: 1.0-1.9) and incidence (SIR 1.5, 95% CI: 1.1-2.1) [4]. Nonetheless, the relationship remains inconclusive because most other studies showed negative results [4,6,7,22]. Our study also did not show a significant association between exposures in the cement industry and lung cancer for workers in the five jobs classifications. In a subcohort analysis, manufacturing workers (all workers except office jobs) who had worked less than 20 years showed increased lung cancer SMR 2.09 (10/4.79, 95% CI: 1.00-3.84). However, there was no significant increase of mortality and incidence for other subgroups (data not shown). It would be hardly possible to interpret these results without exposure data, because there was no increase of lung cancer risk for workers who worked more than 20 years. However, it may be suggestive of a relationship between cement dust exposure and lung cancer to some degree. Therefore, a follow-up study is needed to elucidate the relationship.

A few studies reported that the rate of colon cancer was higher in cement workers due to the inhalation of cement dust [7,8]. Notably, right side colon cancer (ascending colon) is reported more frequently, because the transit time of the right colon is longer than that of the left colon, which means longer contact with Cr^{6+} [24]. In our study, however, there were no significantly increased risks of colon or rectal cancers.

Our study has a few limitations. First, we could not obtain data on confounding factors, such as cigarette smoking and Helicobacter pylori infection, which is known as a risk factor of stomach cancer [25]. For example, smoking is a well-known major risk factor for lung cancer and, without controlling for smoking rates, the resultant cancer risks could be distorted. Thus, if the smoking rate of cement workers were much lower than that of the general male population, SMR or SIR would show low risks of lung cancer and mask the carcinogenic effect of Cr^{6+} exposure. Second, cohort subjects were divided into five groups by their last department. Some proportion of workers might have changed their department during the observational period, despite the distinct characteristics among those jobs. However, we could not control the misclassification of jobs due to the lack of job history information. Third, a quantitative exposure assessment of dust was not conducted in our study. There needs to be an evaluation of the relationships between dust exposure and cancers using quantitative exposure data in the near future.

In conclusion, stomach cancer incidence was higher (SIR 1.56, 95% CI: 1.02-2.26) in cement production workers in the five job classifications. However, there was no increased risk of stomach cancer mortality. These results support the potential relationship between cement dust exposure and stomach cancer, but due to the inconsistency between mortality and incidence, they can provide only limited evidence.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Acknowledgements

This study was supported by the intramural research fund of the Occupational Safety and Health Research Institute (OSHRI).

References

1. Meo SA. Health hazards of cement dust. Saudi Med J 2004;25:1153-9.
2. Mwaiselage J, Bråtveit M, Moen B, Mashalla Y. Cement dust exposure and ventilatory function impairment: an exposure-response study. J Occup Environ Med 2004;46:658-67.
3. Mwaiselage J, Bråtveit M, Moen BE, Mashalla Y. Respiratory symptoms and chronic obstructive pulmonary disease among cement factory workers. Scand J Work Environ Health 2005; 31:316-23.
4. Vestbo J, Knudsen KM, Raffn E, Korsgaard B, Rasmussen FV. Exposure to cement dust at a Portland cement factory and the risk of cancer. Br J Ind Med 1991;48:803-7.
5. Smailyte G, Kurtinaitis J, Andersen A. Mortality and cancer incidence among Lithuanian cement producing workers. Occup Environ Med 2004;61:529-34.
6. McDowall ME. A mortality study of cement workers. Br J Ind Med 1984;41:179-82.
7. Jakobsson K, Horstmann V, Welinder H. Mortality and cancer morbidity among cement workers. Br J Ind Med 1993;50:264-72.
8. Jakobsson K, Attewell R, Hultgren B, Sjöland K. Gastrointestinal cancer among cement workers. A case-referent study. Int Arch Occup Environ Health 1990;62:337-40.
9. IARC Monographs on the evaluation of carcinogenic risks to humans. Volume 49. Chromium, nickel, and welding. Lyon (France): International Agency for Research on Cancer; 1990. p. 49-256.
10. Life table analysis system (LTAS) [Internet]. Atlanta (GA): National Institute for Occupational Safety and Health. 2007 [cited 2009 Nov 3]. Available from: http://www.cdc.gov/niosh/ltas/.
11. Daly L. Simple SAS macros for the calculation of exact binomial and Poisson confidence limits. Comput Biol Med 1992;22:351-61.
12. Robinson CF, Schnorr TM, Cassinelli RT 2nd, Calvert GM, Steenland NK, Gersic CM, Schubauer-Berigan MK. Tenth revision U.S. mortality rates for use with the NIOSH Life Table Analysis System. J Occup Environ Med 2006;48:662-7.
13. Seldén AI, Berg NP, Lundgren EA, Hillerdal G, Wik NG, Ohlson CG, Bodin LS. Exposure to tremolite asbestos and respiratory health in Swedish dolomite workers. Occup Environ Med 2001;58:670-7.
14. Kullman GJ, Greife AL, Costello J, Hearl FJ. Occupational exposures to fibers and quartz at 19 crushed stone mining and milling operations. Am J Ind Med 1995;27:641-60.
15. IARC monographs on the evaluation of carcinogenic risks to humans. Volume 68. Silica, some silicates, coal dust and para-aramid fibrils. Lyon (France): International Agency for Research on Cancer; 1997. p. 41-242.
16. Schuhmacher M, Domingo JL, Garreta J. Pollutants emitted by a cement plant: health risks for the population living in the neighborhood. Environ Res 2004;95:198-206.
17. Fatima SK, Prabhavathi PA, Padmavathi P, Reddy PP. Analysis of chromosomal aberrations in men occupationally exposed to cement dust. Mutat Res 2001;490:179-86.
18. Fatima SK, Prabhavathi PA, Prasad MH, Padmavathi P, Reddy PP. Frequencies of sister chromatid exchanges in lymphocytes of Portland cement factory workers. Bull Environ Contam Toxicol 1995;55:704-8.
19. Rafnsson V, Jóhannesdóttir SG. Mortality among masons in Iceland. Br J Ind Med 1986;43:522-5.
20. Olsen J, Sabroe S. Occupational causes of laryngeal cancer. J Epidemiol Community Health 1984;38:117-21.
21. Amandus HE. Mortality from stomach cancer in United States cement plant and quarry workers, 1950-80. Br J Ind Med 1986;43:526-8.
22. Dab W, Rossignol M, Luce D, Bénichou J, Marconi A, Clément P, Aubier M, Zmirou-Navier D, Abenhaim L. Cancer mortality study among French cement production workers. Int Arch Occup Environ Health 2011;84:167-73.
23. Fox AJ, Collier PF. Low mortality rates in industrial cohort studies due to selection for work and survival in the industry. Br J Prev Soc Med 1976;30:225-30.
24. Jakobsson K, Albin M, Hagmar L. Asbestos, cement, and cancer in the right part of the colon. Occup Environ Med 1994;51:95-101.
25. Forman D, Newell DG, Fullerton F, Yarnell JW, Stacey AR, Wald N, Sitas F. Association between infection with Helicobacter pylori and risk of gastric cancer: evidence from a prospective investigation. BMJ 1991;302:1302-5.