

Health hazards of cement dust

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ABSTRACT

Even in the 21st century, millions of people are working daily in a dusty environment. They are exposed to different types of health hazards such as fume, gases and dust, which are risk factors in developing occupational disease. Cement industry is involved in the development of structure of this advanced and modern world but generates dust during its production. Cement dust causes lung function impairment, chronic obstructive lung disease, restrictive lung disease, pneumoconiosis and carcinoma of the lungs, stomach and colon. Other studies have shown that cement dust may enter into the systemic circulation and thereby reach the essentially all the organs of body and affects the different tissues including heart, liver, spleen, bone, muscles and hairs and ultimately affecting their micro-structure and physiological performance. Most of the studies have been previously attempted to evaluate the effects of cement dust exposure on the basis of spirometry or radiology, or both. However, collective effort describing the general effects of cement dust on different organ and systems in humans or animals, or both has not been published. Therefore, the aim of this review is to gather the potential toxic effects of cement dust and to minimize the health risks in cement mill workers by providing them with information regarding the hazards of cement dust.

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Before the invention of cement, the earlier structures were composed of earth raised in the form of walls or domes by ramming successive layers of stone blocks, set one above another without the aid of any cementing material. The stability of walls was derived entirely from the regular placing of heavy masses of stones without any assistance from adhesion. With the passage of time, people began to construct their homes with a mixture of sand and a cementitious material consisting of lime or gypsum, or both. From the 12th century onward, the quality was improved and the lime being well burnt and well sifted. In 1824, hard lime stone was used and mixed with clay grinding to fine slurry with water and then broke the mixture into suitable lumps and calcines them in furnace, similar to a lime kiln until the carbonic acid was expelled. The mixture was so calcined and ground beat or rolled to a fine powder. The name Portland cement was given to the product from a resemblance of the color of cement after setting to Portland stone.¹ The Portland cement may be

defined as a gray powder-like adhesive substance.² It may also be defined as mineral dust, when mixed with a water it forms a plaster like adhesive mass.³

Contents of portland cement. Cement is a mixture of Calcium oxide (CaO) (62-66%), Silicon oxide (SiO₂) (19-22%), Aluminum tri-oxide (Al₂O₃) (4%-8%), Ferric oxide (Fe₂O₃) (2-5%), Magnesium oxide (MgO) (1-2%)⁴ and also Selenium,⁵ Thallium⁶ and other impurities.⁷

Types and production of cement. There are 2 main types of cement, natural and artificial. The natural cement is obtained from natural material having a cement-like structure and requires only calcining and grinding to yield cement powder. Artificial cement is also called Portland cement, there are different types of portland cement such as ordinary or rapid-hardening, sulphate resisting, white, colored, low heat, masonry, hydrophobic, water-replant, expanding and non-shrinking, high aluminum, blast furnace and oil well cement.¹ Portland cement is produced in cement factories under consideration of different substances

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especially the limestone and clay, which are heated to approximately 1250°C for a period of 90 minutes. The chemical reactions, which take place during heating process produces 4 major phases, which are known as Tri-calcium silicate, Di-calcium silicate, Ferrite phase and Tri-calcium aluminates phases. The final product is obtained by grinding its contents with 5% gypsum. When cement gets in contact with water, it hydrates quickly at different rates for the different phases.⁸

Exposure to cement dust. Cement mill workers are exposed to dust at various manufacturing and production processes, such as quarrying and handling of raw materials, during grinding the clinker, blending, packing and shipping of the finished products.⁹

Pathogenesis. The aerodynamic diameter of cement particles range from 0.05-5.0 micrometer in diameter. These particles are respirable in size; hence, Portland cement is important as a potential cause of occupational lung disease.² This particle size distribution would make the tracheobronchial respiratory zone, the primary target of cement deposition.⁴ The main route of entry of cement dust particles in the body is the respiratory tract or the gastrointestinal tract, or both by inhalation or swallowing. Both routes, especially the respiratory tract are exposed to numerous potentially harmful substances in the cement mill environment.¹⁰ The physical properties that are of importance include particle size and density, shape and penetrability, surface area, electrostatic charge, and hygroscopicity. Among the more important chemical properties influencing the respiratory tract's response is the acidity or alkalinity of the inhaled agent.¹¹ The deposition of inhaled material is primarily dependent on particle size and is best described in forms of an aerodynamic diameter. All particles with an aerodynamic diameter in excess of 10µm are deposited on the mucous membrane in the nose and pharynx and particles between 3 and 10µm in diameter can be deposited throughout the tracheobronchial tree. Particles between 0.1 and 3µm in diameter are mostly deposited within the alveoli and particles smaller than 0.1µm remain in the air stream and are exhaled.¹² The pathogenesis is most probably due to its irritating, sensitizing and pneumocytic properties.

Health effects. General clinical manifestations. High concentration or prolonged inhalation, or both of cement dust in cement industry workers can provoke clinical symptoms and inflammatory response that may result in functional and structural abnormalities.⁷ The most frequently reported clinical features in cement mill workers are chronic cough and phlegm production, impairment of lung function, chest tightness, obstructive and restrictive lung disease, skin irritation, conjunctivitis, stomach ache, headache,

fatigue^{4,13} and carcinoma of lung, stomach and colon.^{14,15} (Table 1)

Respiratory system. Larynx. Vestbo et al¹⁶ observed the relation between exposure to cement dust and cancer, and showed the increased risk of overall cancer among cement workers and also observed 14 cases of respiratory cancer among men with more than 20 years of exposure to cement dust. Maier et al¹⁷ found an increased risk of laryngeal cancer in subjects chronically exposed to cement dust, pine wood dust and coal tar products. The risk associated with cement dust and coal tar product was predominantly related to supra glottis cancer. In addition, Noor et al¹⁸ observed that, apart from respiratory diseases, cement dust also cause the cancer of larynx and lung. Oslen and Sabroe¹⁹ reported the high risk for laryngeal cancer in semiskilled and unskilled workers exposed to dust especially in the cement industries. The study hypothesis was that exposure to chromium or nickel increases the incidence rate of laryngeal cancer.

Lungs. Jenny et al,²⁰ El-Sewefy et al,⁸ Saric et al,²¹ Oleru,⁴ Alakija et al²² and Yang et al,² reported that the mean value of lung function parameter, forced vital capacity (FVC) and forced expiratory volume in first second (FEV₁) in cement mill workers were significantly decreased compared to their matched controls. Oleru⁴ and Siracusa et al²³ showed that, the lung function parameters, FVC and FEV₁ were decreased with duration of employment in cement industry. Similarly, Gomzi et al²⁴ demonstrated that, the lung function indices FVC and FEV₁ in cement mill workers were negatively related with duration of exposure. Alakija et al²² also showed that cement mill workers had a consistent decline in FVC and FEV₁ with prolonged years of service in the cement industry. In addition, Meo et al²⁵ demonstrated that, lung function indices FVC and FEV₁ decreased in cement mill workers and these parameters were further decreased with increased duration of exposure. Alakija et al²² showed that, in cement mill workers peak expiratory flow (PEF) was decreased with prolonged years of exposure in cement industry. They also reported that workers who had spent less than 5-years in cement industry had a significantly higher PEF than workers who had put in more than 15-years of service. Mengesha and Bekele²⁶ observed a significant decrease in Forced expiratory flow from 25-75% (FEF 25-75%) and PEF in cement mill workers compared to their control. Similarly, Meo et al,²⁵ demonstrated a decreased PEF and maximal voluntary ventilation (MVV) in cement mill workers. These parameters were also further decreased with increased duration of exposure. Kalacic²⁷ reported that restrictive ventilatory changes appear in cement mill workers. These changes appeared to be less prominent initially and became more prominent at later stages. In addition,

Table 1 - Hazards of cement dust on different organs.

Systems	Organs	Effects of cement dust
Respiratory system	Lungs	Cough and phlegm production, chest tightness, impairment of lung function, obstructive and restrictive lung disease, pleural thickening, fibrosis, emphysema, lung nodulation, pneumoconiosis and carcinoma of lung.
Gastrointestinal system	Oral cavity	Mechanical trauma, mucosal inflammation, loss of tooth surface, periodontal disease, dental abrasion and dental caries.
	Liver	Diffuse swelling and proliferation of sinusoidal (hepatic) lining cells, sarcoid type granulomas, perisinusoidal and portal fibrosis and hepatic lesions.
	Stomach	Stomach ache and cancer of stomach
Central nervous system	Brain	Headache and fatigue
Lymphatic system	Spleen	Diminished lymphatic tissue and splenic lesions
Miscellaneous	Eye, skin and bone	Irritation of eyes, runny eyes and conjunctivitis, skin irritation, itching, skin boil and burn, osteonecrosis, lesion of the humerus, thinning of the cortex and reduction of epiphyseal cartilage.

Oleru⁴ reported that large number of cement mill workers were suffered from restrictive lung disease. Meo et al²⁵ also suggested a restrictive type of pattern with a significantly decreased FVC, FEV₁ and an increase in the FEV₁/FVC ratio in cement mill workers. In restrictive lung disorders, the forced vital capacity is reduced, but does not slow the delivery of air so that FEV₁ is similarly reduced but the FEV₁/FVC ratio remains normal or even increased.²⁸ On chest radiography, Scansetti et al²⁹ found pleural thickening in one quarter of cases out of 100 Italian cement mill workers. Similarly, Abrons et al³⁰ observed the prevalence rate of 2% for pleural abnormalities predominantly bilateral diffuse pleural thickening in cement mill workers. In addition, Meo³¹ demonstrated that pulmonary radiographic abnormalities such as interstitial lung disease, pleural thickening and chronic bronchitis in cement mill workers. Vyskocil,³² Popovic,³³ Izycki et al³⁴ and Laraqui Hossini et al³⁵ demonstrate that cement mill workers suffered from chronic bronchitis compared to controls. In addition, Macie Jewska and Bielichowska-Cybula,³⁶ also found chronic bronchitis, tissue fibrosis and emphysema in cement mill workers. Prosperi and Barsi,³⁷ Sander³⁸ and Gardner et al³⁹ found micro nodulation in the lungs after prolong exposure in cement industry. Maestrelli et al⁴⁰ reported radiographic changes of pneumoconiosis among 7.2% in Italian cement mill workers. In addition, Herrera et al⁴¹ found 1.6% of pneumoconiosis in cement mill workers in Venezuela. Similarly, Popovic⁴² identified pneumoconiosis in 17.4% in Yugoslavian cement workers.

In addition, Pimental and Menezes⁴³ observed the pulmonary granulomas in cement mill workers. Stancari and Penazzato⁴⁴ and Popovic³³ reported that the prevalence of lung tuberculosis among cement workers was found to be equal to or even less than the general population. Similarly, Gardner et al³⁹ and Sander³⁸ reported that the incidence of tuberculosis of the lungs is low in cement mill workers than controls. Zhang⁴⁵ reported the 3 autopsy cases exposed to finished cement dust and found that pathologic changes relevant to cement dust in the lungs were similar, including distribution of numerous dust macules and focal emphysema formed in the parenchyma of lungs. Additionally, cement bodies (collection of cement dust particles at one place) were obtained in the dust macules by means of electron diaphanous x-ray analysis. The elements of dust foci and digested concentrates of the lungs were measured, and the morphology of dust granules was studied. Results indicated that the elements of intrapulmonary dust were just the same as those of finished-cement dust. Therefore, the pulmonary lesions obtained were considered to be induced by finished cement dust.

Gastro intestinal system. Oral cavity and teeth. Struzak-Wysokinska and Bozyk⁴⁶ observed the condition of the oral mucosa in workers of cement plant. Clinical examination demonstrated features of mechanical trauma and oral mucosal inflammation in all workers exposed to cement dust. Tuominen and Tuominen⁴⁷ observed the affect of cement and stone dust on teeth, the tooth surface loss was higher (72.2%) in exposed workers than

(48.4%) controls. In both the maxillae and the mandible, the amount of tooth surface loss was greater in the exposed workers than in the controls and both anterior and posterior teeth were affected. These findings indicate that tooth surface loss caused by work-related dust should be considered an occupational hazard. Bozyk and Owczarek⁴⁸ showed that the intensity of the parodontal disease was greater in workers exposed to cement dust than in controls and a very high incidence of deep parodontitis was noted in young workers of the cement plant. Petersen and Henmar⁴⁹ evaluate the oral health condition of workers in the stone work industry and describe the prevalence and severity of dental diseases. They reported that workers exposed to dust revealed a high prevalence of dental caries with number of decayed, missing and filled surfaces along with poor periodontal conditions. They also reported the cases of teeth with gingivitis, calculus and pockets deeper than 5 mm. The prevalence of dental abrasion was 100% in particular, abrasions were observed on the front teeth. However, the severity of abrasions and the affection ratio increased by duration of exposure to dust.

Liver. Pimental and Menezes⁴³ described diffuse swelling and proliferation of sinusoidal (hepatic) lining cells, sarcoid type granulomas and perisinusoidal and portal fibrosis in the liver of cement mill workers. These changes are closely related to inhaled cement dust. In their opinion, the inhaled cement particles reach the liver by the blood stream and produce different types of hepatic lesions and they also found cement dust inclusions in the liver.

Stomach. Oleru⁴ found that cement dust cause stomachache. It has been also reported that Portland cement contains chromium in its hexa-valent form, which is an established carcinogen and causes the cancer of stomach.⁵⁰ In addition, Amandus⁵¹ studied the mortality of United States of America cement plant and quarry workers and reported the vital status of a cohort of 5292 men who had been employed for at least 5-years in a cement plant between 1950 and 1980. The mortality experience was evaluated for 4231 white men for whom complete work histories and demographic information were obtained and suggested that, the deaths from stomach cancer were significantly increased during 1965-1974 but not over the entire follow up period (1950-1980).

Peritoneum. Kolev and Shumkov⁵² studied the morphological changes occurring upon intra peritoneal application of cement. Initially, the changes in the peritoneal cavity were mainly necrotic and exudative, while after subsiding; granuloma was formed around the un-eliminated dust particles. Kolev and Dimitrov⁵³ submitted the results on the influence of cement dust, introduced into the peritoneal cavity of experimental animals

and reported that the peritoneal cavity is more suitable for investigation of the cumulative action of dust with fibrous and toxic effect.

Colon. Jakobsson et al⁵⁰ reported that cement dust causes the cancer of the colon.

Urinary system. Kidney. Brockhaus et al⁶ reported that thallium containing atmospheric dust caused by emission of the cement plant effects the population living around the cement plant and exhibited increased urinary concentration of thallium level in these subjects. Similarly, Schaller et al⁵⁴ showed the conformity of the presence of thallium in the urine of cement mill workers. He suggested that, it must be considered a suitable parameter for the assessment of the presence of thallium in the body of cement mill workers. In part, the group of persons investigated revealed excretions of thallium slightly or moderately above the normal level. It may be possible that increased concentration of thallium may be deposited and affects the nephron.

Cardiovascular system. Heart. Maciejewska⁵⁵ induced siliceous dust by intra-tracheal administration in rats and found an increased level of collagen due to fibrosis in heart of the rats. The findings of this animal study indicate that silica is deposited in heart when introduced by intra-tracheal route and caused fibrosis; hence the collagen contents are increased in the heart.

Head and neck. Maier et al⁵⁶ suggested that workers in the construction industry carry an increased risk for head and neck cancer due to exposure of occupational carcinogenic agents. These substances include cement dust, asbestos, tar products, metal dust, wood dust, and paints. Maier et al⁵⁷ conducted a study on the number of subjects exposed to wood dust, organic chemicals, coal products or to cement and observed an increased relative risk for head and neck cancer. The cancer risk due to cement exhibition showed a positive correlation to the duration of exposition.

Eyes. Cement dust has been identified as an eye allergen and can cause runny eyes, and conjunctivitis.⁴ In addition Sanderson et al⁵⁸ found that workers at a Portland cement plant had experienced acute eye irritation when performing maintenance inside a kiln unit of a cement plant.

Skin and hairs. Lachapelle⁵⁹ described that, cement dust has been identified as a skin problem factor that can cause itching, skin allergen irritant and also cause skin boils and burn. Reichrtova⁶⁰ found the bioaccumulation of industrial cement dust components in laboratory animals exposed by inhalation of cement emission and reported that, the chemical components of the cement dust particles inhaled by animals are accumulated in the hairs of the exposed animals. In addition, Brockhaus et al⁶ reported that thallium containing atmospheric dust caused by emission of the cement plant effects the

population living around the cement plant and the residents exhibited increased hair thallium level.

Lymphatic system. Spleen and thymus. Dvorianovich et al⁶¹ conducted a study on the effect of administration of clinkers and cement dust and observed the harmful effect of industrial cement dust on the lymphatic organs especially spleen and thymus. They observed diminished lymphatic tissue, decreased DNA, RNA and total protein levels. Maciejewska⁵⁵ induced 50mg of siliceous dust by intra-tracheal administration in rats and tested the affected rats and found an increased level of collagen due to fibrosis in spleen of the rats. This animal study finding showed that silica is deposited in the spleen when introduced by intra-tracheal route and caused fibrosis; hence, the collagen contents are increased in spleen.

Musculoskeletal system. Bone. Reichrtova⁶⁰ found the bioaccumulation of industrial cement dust components in laboratory animals exposed by inhalation of cement emission and reported that, the chemical components of the cement dust particles inhaled by animals are accumulated in bones of the exposed animals. Pond et al,⁶² added the cement kiln dust (CKD) in the feed of weanling pig for a 42 days experiment and found that the body weight gain was depressed and also observed lesions of the humerus bone along with osteonecrosis, thinning of cortex and reduction of epiphyseal cartilage.

Muscles. Meo et al²⁵ showed the decreased performance of intercostals muscles on the basis of electromyogram findings and also suggested that when cement dust enters into the blood stream it may also reaches the skeletal muscles and affects their structure and performance. Therefore, the intercostals muscles of cement mill workers exhibited reduced performance due to the deposition of cement dust in muscle cells sarcoplasm and is probably associated with the changes in muscle structure.

Congenital abnormalities and disabilities. Dolgner et al⁶³ reported that thallium dust generated during cement production causes congenital malformation in the population living in the vicinity of the cement plant. These congenital abnormalities were cleft lip and palate, facial hemangioma, icterus neonatorum, swelling on the back of hands and feet, inguinal hernia, umbilical hernia, lumbar meningomyelocele and ventricular septal defect. However, lumbar meningomyelocele and ventricular septal defect later may cause medical disabilities.

Based on the above literature described, it has been demonstrated that cement dust causes chronic obstructive lung disease, restrictive lung disease, lung function impairment, pneumoconiosis, and carcinoma of larynx, lungs, stomach and colon. In addition, it has been suggested that, the components of cement dust also enter into blood stream and may

also reaching the different tissues of the body including heart, liver, spleen, bone, muscles and hairs, and affecting their micro-structure and physiological performance.

Recommendations and preventive measures. Keeping in view the hazards of cement dust it is advisable; therefore, the cement industry management, their workers and health officials should work together to adopt technical preventive measures, such as well ventilated work areas and workers should wear appropriate apparel, mask, safety goggles. It is also suggested that cement mill workers must undergo pre-employment and periodic medical surveillance tests. These measures would help to identify susceptible workers in due time and improve the technical preventive measures that will decrease the risk of occupational hazards in the cement industrial workers.

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