MINI-REVIEW

Effects of SiO_2 in Turkish Natural Stones on Cancer Development

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Abstract

In materials science, one of the new concerns in the construction industry, it is well established that mineral dust from rocks (stones) has adverse effects on human health. For instance, it is suspected that some mineral dusts in particular leads to occupational diseases, including lung cancer. The present research concerned the relationship between cancer and those workers who work in Turkish construction industry and quarries and are exposed to silica mineral dust from natural stones. One focus was cancer prevention methods applied in-site. In mining and construction industry where stone dust is widely used, silicosis induced lung cancer is frequently seen. Cancer cases which are seen across the regions mostly affected by silica containing dust in Turkey were identified and a survey was conducted of the methods to protect workers in the construction industry from exposure to silica dust.

Keywords: Natural stones - dusts - silica - cancer - Turkish worksites

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Introduction

Stone dust is particles suspended in air with a grain size less than 100 μ. Dust is classified into fibrogenic, toxic, carcinogen, radioactive, allergic etc. according their biological effects. Some dust can reach up to the lungs. Dust that reaches into lung alveoli and has a grain size of 0.5 to 5 μ is called "inhalable dust". Especially, workers in mining and construction industries are highly exposed to this type of dust (Woźniak, 1996; Gökduman, 2009).

One of the stone dust causing occupational diseases is "silica" which is a chemical compound consisting silicon dioxide (SiO_2). It has two types; crystalline and amorphous. It is also found insome polymorphic forms such as crystalline silica, alpha quartz, beta quartz, tridymite,cristobalite, keatite, coecite, stishovite and moganite. Being occupationally exposed to silica dust is a severe and usually unavoidable health problem. Many occupational deaths of number is unknown or not reported are caused by diseases such as silicosis, tuberculosis (TB) and scleroderma due to silica dust (Gökduman, 2009).

Today, occurrence rate of various cancer types is 80 to 90% depending on the environment. In health terms, environment can be defined as physical environment that contains soil, water and air around us, biological environment and social environment and they are all interact with each other and have an impact on the structure of genes (Aksoy, 2002).

The co-occurrence of lung cancer and silicosis implies a relationship between silicosis and lung cancer. Statistical data from studies carried out on this field in recent years demonstrate that silicosis is not a factor facilitating the lung cancer. An increase in the frequency of lung cancer among quarry and foundry workers depends mainly on the carcinogen substances that would be found in those products handled in foundries. Particularly sand treated with mineral oils contains carcinogen substances (polycyclic aromatics) (MDHS, 2005).

Methods of protection against occupational diseases can be summarized as follows; pre-employment examination, intermittent control examination and health training. During the pre-employment examination, the working environment and handled materials are evaluated in terms of their risk potential for a prospective employee and those with an unfavorable risk potential are ensured to be directed to other jobs. For example, smoking is extremely risk for a person who is working in a place with silicate and asbestos exposure. During intermittent control examinations, based on the disease type, examinations that may allow early diagnosis are performed. Potential risks and prevention methods are included in health training according to the nature of work undertaken (Bilir and Yıldız, 2004).

Being found in natural stone dust, silica (SiO_2) may lead to silicosis depending on its ratio (Neukirch, 1994). During literature review, it was found that there exist no adequate studies describing the effects of natural stone dust on cancer and the topic also was examined by making comparisons among natural stones in a manner that all natural stone types were included. This study was conducted in order to comparatively examine the SiO_2 content of various stone dusts on cancer.

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Silicate Content of Natural Stones

In the world natural stone production, carbonate stones rank first with 54.80%, silicate stones second with 39.90% and followed by slate and other stones with 5.30% (Yüzer, 2008). Around the world, existence of silicate stones up to 40% urged us to emphasize on improving the working conditions for silicate stone quarry workers and raising awareness among them. Silica containing stone dust is important to human health and is a leading factor causing occupational diseases.

Among natural stone types, there are great differences in terms of SiO_2 content (Table 1). Particularly, granites, a magmatic rock, have a large proportion of SiO_2 varying between 74.75% and 54.55%. Andesite, Basalt and Diabase have also considerably high SiO_2 contents. Marble and travertine contain very low silica. Only Elazığ cherry colored (Rosso Levanto) marble has a substantially high content of SiO_2 reaching 28.35%. Quarry workers are exposed to various ratios of SiO_2 depending on the stone types found in the quarry where they work. For those workers exposed to stone dust, the risk of silicosis development varies based on the SiO_2 ratio of the stone type.

The highest fibrogenic effect is produced by quartz (SiO_2) in inhalable dust. According to Stoceset et al. (1970), the richer the dust particles in terms of quartz, the higher the risk of disease they can lead to. Furthermore, the quartz content in inhalable dust must not exceed 5%. Quartz content is determined by using Analytic Methods such as XRD Spectrometry, Infrared Spectrometry and Colorimetric Spectrophotometry (Gökduman, 2009). As seen in Table 1, among Turkish natural stones, granite, andesite, diabase and Elazığ Cherry Colored marble have substantially higher SiO_2 content than this value.

Whereas limestone has a SiO_2 ratio of about 1% and quarry stones from Pınarhisar and Vize areas in the Thrace region have a SiO_2 ratio of 15%, it is determined via chemical analysis carried out in Canada ACME Laboratory that limestone from historical buildings in the region contains silicon dioxide up to 11% (Dal, 2008) Being exposed to sand dust generated by quarries, cement and lime plants, number of cancer cases gradually increase among the people living in the region. During mechanical tests carried out in the Building laboratory, people are exposed to dust. Especially, all measures must be taken against dust when conducting Bohme Wear Resistance Test (Figure 1).

Carcinogen Effects of Silica Dust

The 21th century marks an increase in various occupational diseases due to inhalation of mineral dusts. Stone dust containing silicate, asbestos etc. toxic minerals increase cancer incidence in Turkey and other countries.

It is closely associated with many considerations related to the life quality of human communities such as geological process, architectural environment that involves integrity between materials and spaces (housings, educational institutions, workplaces etc.). In construction industry, some word areas with the highest risk of silicosis are cement-lime production plants, quarries-tile-kilns, road-dam construction, tunneling, civil engineering works, ceramics-glass crushing and grinding, casting works etc.

When looked at Turkey's geological map, granitic, volcanic and sedimentary rocks rich in quartz cover a vast area. Quartz is the most widely found mineral in nature. Silica, a white or colorless crystalline compound, SiO_2,

Table 1. SiO_2 Contents of Natural Stones Widely Used in Turkey (İstanbul, 2001)

Natural Stones	Name of stones	SiO_2 (%)
Marble	Agean Bordeaux Marble	7.50
Marble	Agean Brown Marble	1.39
Marble	Afyon Tigerskin Marble	0.14
Marble	Agean White Marble	0.24
Marble	Akşehir Black Marble (Konya)	0.49
Marble	Bartın Beige Marble	2.00
Marble	Bilecik Pink-Dry Rose Marble	1.04
Marble	Burdur Beige Marble	0.15
Marble	Burdur Brown Marble	1.27
Marble	Bursa Beige Marble	<0.10
Marble	Denizli Pink Marble	0.10
Marble	Dinar Beige Marble (Afyon)	<0.10
Marble	Diyarbakır Beige Marble	0.60
Marble	Diyarbakır Pınk Marble	0.30
Marble	Balıkkesir Dove Marble	0.10
Marble	Elazığ Cherry Marble	28.35
Marble	Gölpazarı Beige (Bilecik)	0.19
Marble	Hazar Pink Marble (Diyarbakır)	1.15
Marble	Karacabey Black Marble (Bursa)	0.30
Marble	Kastamonu Eflani Beige Marble	0.75
Marble	Kayseri Kamelyon Marble	5.20
Marble	Leopard Marble (Eskişehir)	1.50
Marble	Manyas White Marble (Balıkesir)	0.20
Marble	Marmara White Marble (İstanbul)	0.01
Marble	Milas Kavaklıdere Marble (Muğla)	0.14
Marble	Muğla White Marble	<0.10
Marble	Mustafa Kemal Paşa Marble	0.21
Marble	Sarıcakaya Beige Marble (Eskişehir)	1.20
Marble	Sazara Rue Marble (Kırklareli)	0.56
Marble	Sivrihisar Beige Marble (Eskişehir)	0.80
Marble	Söğüt Beige Marble (Bilecik)	0.51
Marble	Süpren Marble (Eskişehir)	0.56
Marble	Taşçılar Crema Nuovo Marble	1.26
Marble	Taşçılar Rosalia Marble	1.26
Marble	Taurus Beige Marble	<0.1
Marble	Taurus Black Marble	2.56
Marble	Uşak Green Marble	4.97
Marble	Uşak White Marble	0.02
Marble	Uşak Yellow Marble	0.47
Marble	Vize Pink Marble (Kırklareli)	1.91
Marble	Yatağan Bianco Rosa Marble (Muğla)	0.17
Travertine	Bucak White Travertine	0.10
Travertine	Denizli Travertine	0.26
Travertine	Denizli Yellow Travertine	0.10
Travertine	Karabük Yellow Travertine	0.35
Travertine	Kütahya Pink Travertine	0.50
Travertine	Kütahya Red Travertine	0.40
Travertine	Sivas Yellow Travertine	0.10
Granite	Aksaray Pink Granite	74.75
Granite	Aksaray Yaylak Granite	72.70
Granite	Ayvalık Granite	54.55
Granite	Bandırma Blue Granite	71.00
Granite	Bergama Gray Granite	66.25
Granite	Giresun Mink Granite	60.80
Granite	Kaman Granite	61.24
Granite	Kırklareli Balaban Granite	68.10
Onyx	Akhisar Onyx	1.40
Andesite	Ankara Andesite	62.10
Limestone	Antalya Limestone	<0.10
Diabase	Gemlik Diabase	48.52
Basalt	İzmir Aliağa Basalt	57.25

Figure 1. In Building Laboratory, Exposure to Stone Dust During Bohme Wear Resistance (Dal, 2008)

exists abundantly as quartz, sand, flint, agate, and many other minerals and is used to manufacture a wide variety of materials, especially glass and concrete. Prolonged intake of silicate, asbestos and beryllium etc. dusts through inhalation causes an increase in connective tissue in the lung and cancer (De Clerk, 1998). Thus, the most widespread dust-induced disease is silicosis. Diseases that develop depending on silica group of minerals are called "dust diseases, pneumoconiosis".

Particles of silica mineral particularly come from quarries, rock crushing fields and ceramics. Other forms of fine-grained quartz and silica deposit in the lungs and they result in silicosis. When stone dust is inhaled for a long period, especially among the quarry miners, silicosis develops in the lungs and a very severe respiratory impairment occurs. Fiber length and diameter have a profound effect on cancer development (Jaenicke, 1982; WHO???, 1986). It is argued that mesothelioma-inducing asbestos fibers and man-made fibers have a length greater than about 8-10μm and a diameter less than 0.25 μm (or 1.5 μm) (Stanton et al., 1981; Timbrell, 1984; Pott, 1997; Miller et al., 1999). From clinical studies, it was found that a fiber diameter of approximately 0.5 μm or less induces mesothelioma (Timbrell, 1983).

Many employees suffer silicosis, lung cancer, tuberculosis and upper respiratory tract diseases due to exposure to crystalline silica found in natural stone dusts. All in all, the allowable upper limit value (TLV) for inhalable quartz dust is 0,25 mg/m^3 and this value is higher than the same value included in miming standards in developed countries. Thus, it is suggested that the applicable regulations must be updated (Gökduman, 2009).

Though the conventional disease form which is induced by the exposure to inorganic natural stone dust is pneumoconiosis, upon exposure, some symptoms such as cough and expectoration, deterioration in lung symptoms and obstructive lung diseases are observed without pneumoconiosis (Becklake, 1985).

Asbestosis was first detected in shipyard workers in Turkey. Being produced by the body attempting to dissolve asbestos fibers, an acid leads to lung injuries. As with asbestos, erionite (alumina silicate) is the main cause of mesothelioma. Alike asbestos fibers, erionite fibers enter the body through respiration, reaching up to lungs and even peritoneum and stick onto tissues and then, cause tumor formation on where they stuck without chemical alteration. If this process continue for a long period, it is likely to have mesothelioma developed on peritoneum, cardiac and intestinal membrane. A direct proportion was found between the prolonged exposure of workers to erionite and development of mesothelioma (Berman and Crump, 2008).

Asbestos fibers are generally used in thermal insulation of buildings, pipes and storing tanks, insulation against fire and reinforcement of building materials. Health hazards due to mineral fibers and grains are not caused by biochemical toxic reaction, but rather by irritation effects related to size, shape, and surface properties of minerals. This situation causes pulmonary purulence and scare tissue or cancer formation in body. The risk of lung cancer caused by asbestos considerably increases with smoking, while larynx, pancreas, esophagus, colon and renal cancer could also develop. Inhalation of dry fibers fragments in air is a great threat. Fibers are less dangerous when combined together, as the number of free fibers is relatively lower in this case. On the other hand, worn thermal insulation materials and asbestos accumulating or worn in the factory or materials with other mineral fibers pose a great danger (Alloway and Ayres, 1997).

Construction materials used in the houses and lands of workers in Turkey could cause cancer. Especially the geologic investigations in Kapadokya area revealed (Ocakoğlu and Ulusay et al., 2006) that three villages used the same stones obtained from surrounding geology of Tuzköy, Karain and Sarıhıdır villages and the same construction materials were also used in residential areas built with local stones. As a result of the investigations, mesothelioma diagnosis was concluded to be caused by erionite. Erionite mineral is found in the composition of tuff stones in this area and causes health hazards by entering in human respiratory system through air transportation. Houses were constructed on erionite soils in these villages, and erionite stones were used in the construction of houses; in addition, agricultural activities are made on erionite soils, and thus people are surrounded by erionite in all sides (Iman, 2001; Roushdy-Hammady, 2001; Carbone et al., 2007). Çermik-village in Diyarbakır, Büyüktatlı town in Afşin County and Mihallıççık county and villages in Eskişehir are some of the samples for cancer cases in Turkey caused by regional geological conditions (Baris et al., 1996).

There are tree fossils in lake sediments dating back to 15-23 million years (Early Miocene) in Kuztepe district of Pelitçik Village located 75 km northwest of Ankara. This Petrified Forest is generally composed of pine and oak tree, and formed by silica rich waters turning plants in silicate through entering plant cells. Here, 10 different types of trees were fossilized (İnan, 2011). Genetic evaluation of people in this village is important for evaluating health status and determining the cancer incidence.

Protection against Exposure to Silica Dust

NIOSH (1991) detected that approximately 1.7 million American workers were subjected to respirable silica dust. In addition, the number of workers subjected to silica dust in industries like mining, construction, and petroleum-gas is quite high. Besides sectors like mining and quarry containing dust, workers in various industries are also subjected silica dust as it is widely present in the production materials, products and environment. No case of exposure above respirable limits was detected in 48% of industries. It is quite possible for workers employed in industries containing silica products or mines to be subjected to silica dust (NIOSH, 2002; Gökduman, 2009).

COSHH (Control of Substances Hazardous to Health Regulations) is not a health institution covering the exposure limits of silica dust, but it includes the regulations that should be obeyed for sampling and it became an obligation to abide by COSHH regulations, because these regulations were formed to prevent problems that could be experiences by workers in the future and to provide constant control if not be controlled. COSHH should also provide workers with the information and training about dangerous respirable dust (Gökduman, 2009) .

In workplaces, dust measurement with MDHS (Methods for Determination of Hazardous Substances) should also be performed in addition to workers' health controls, safety precautions and trainings. MDHS helps to measure repirable dust concentrations in air and work places. These documents aim to determine the method with the highest performance and have established the conformity to European and international standards (NIOSH, 2002).

For measuring the human health threatening dusts in air, sampling should be made with various dust meters. Tools used for dust measurement function on gravimetric and particle counting basis, and a suitable sampling method should be chosen for an efficient sampling. Furthermore, sampling should be performed for a certain period of time depending on the dustiness level of environment when respiration level of workers increases. According to the regulation regarding the dust management in Mining and Quarries Enterprises and Tunnel Construction, dust limit value is defined as "Threshold Limit Value (TLV)", and accordingly, workers cannot be employed in workplaces with dust intensity value over TLV, and thus, preventive studies should be carried out to eliminate dust formation or settle the dust (Gökduman, 2009) .

Profession-related cancers are one type of professional diseases. The same principles for protection from professional diseases are applied. In practice, the real reason of cancer is not known in the majority of cancer cases in human. However, protection is even more probable in professional cancers than other types of cancer. There are possible technical and medical prevention possibilities in protection. The aim of technical protection measurements for professional cancers is to control the source that causes cancer. From this regard, the most accurate application is to eliminate and not use carcinogen material. Different substitutions could be found for carcinogenic materials and non-carcinogenic materials could be used instead. One of the commonly known examples is the use of certain synthetic fiber materials instead of asbestos. However, this cannot be applicable in certain situations and the material is a necessity for the continuation of work process. In this case, certain engineering applications, mostly composed of effective ventilation systems and making process within a closed system, are applied. However, personal protection tools like mask, gloves etc. will be useful in addition to application on source basis. Sometimes, carcinogenic material is used in firmly closed mechanisms or robots are employed to continue the process (Bilir and Yıldız, 2004) .

People working in stone and mining pits for long periods of time should be periodically followed and their findings should be evaluated (Ulm, 2004). Workers in mining and stone industry should be examined for respiration function tests, films, smoking status, nutrition conditions, clinical findings, acute coughing, secretion, respiratory problems and breast pains; in addition, nurse and doctor should be present in the working area. The elimination of silicosis throughout the world is included in the international program of World Health Organization in 1995. Sufficient and applicable protection programs should be prepared to provide sources for applying primary and secondary protection in local, regional and global activity programs, and to determine epidemiological surveillance (Ar and Mahjub, 2003).

Conclusions

Cancer caused by geological structure is a common case in Turkey and World; therefore, medical geology in cancer management has rapidly developed throughout the world. Medical Geology Sub-Commission was formed, affiliated to Cancer Counseling Commission in the Ministry of Health, and Medical Geology Project was started in MTA General Directorate. Medical Geology has come into prominence as cancer cases are firmly related to hydrogeology, hydrochemistry, geochemistry, mineralogy, and mining. Protection from cancer could be mainly achieved by controlling environmental effects with national and international studies.

Medical geology engineers and construction material experts emphasize the importance of medical geology for the selection of construction materials used in houses and cultural living areas. Many elements are composed of minerals and stones. People living with geological structuresreceive different amounts of chemical elements in different ways. Some major elements like SiO_2 also threaten human health.

There are links between disease and soil elements in geochemical maps. In Turkey, harmful elements have negative effects on human health, as well. In order to minimize the negative effects on future generation that could be caused by these reasons, it is quite important to prepare geochemical maps, determine mineralogical structure of stones, and take necessary precautions for possible diseases determined through comparisons with diseases maps prepared by physicians. For solution of problems affecting human health and related to construction sector, lessons of professional diseases should be included or increased in the curriculum of

Civil Engineering, Mining, Chemistry and Architecture Schools, and studies should be performed on health problems of workers in construction and mining industries by organizing interdisciplinary studies.

Dust of natural stones causes respiratory symptoms in workers and thus, precautions should be taken to reduce dust concentration depending on the silica composition of natural stone, and workers should be informed about the matter. Safety for professional disease should be maximized in this field. Health staffs employed in workplaces to protect worker's health, make early diagnosis for cancer, inspect the precautions taken against inhaled dusts, keep annual follow-ups of workers, and detect the type of dusts in air would reduce the rate of death, especially due to lung cancer (Gökduman, 2009).

Workers in Asian countries are also exposed to silisium extracted from rocks with silica content in Iran. Workers in socioeconomic group with low relation between nutrition and cancer (sustain immune system) are employed in this region. Certain health problems like respiratory diseases were determined in the medical screening studies implemented on workers in this region (Bahramı, 2008). Workers' nutrition should strengthen their immune systems, their exposure to silisium should be kept under standard limits and legal regulations should be prepared in this regard.

The cooperation of professional health nurses and doctors facilitates the protection of worker health and early diagnosis of cancer. Doctors and nurses should organize the medical examination of workers and relevant trainings. It is necessary to keep records of workers' medical and professional history, interview with each worker, make general clinical examination, secretion analysis and breast examination, follow lung x-ray annually, make respiratory function test, and make advanced tests including cytology tests, computerized axial tomography and bronchoscopy. Health staffs sensitive to such matters as quitting smoking, consuming foods to strengthen immune system, using safety masks in workplace, minimizing dust-related processes and taking precautions to reduce exposure to dust should also be careful that employer fulfills the requirements of procedures in this document (Çalışma ve Sosyal Güvenlik Bakanlığı Asbestle Çalışmalarda Sağlık ve Güvenlik Önlemleri Hakkında Yönetmelik). Implementation of all precautions required for industries concerning natural stone dusts with high SiO_2 content should be inspected by company executives, and workers should be informed about this matter. Rock and cancer experts from different disciplines should organize activities like projects, training symposiums, conference etc. to deal with the matter together and emphasize the importance of the matter.

Following procedures should be applied to workers employed in areas exposed to silica

✓ Prevention of stone dusts (wet working, suitable ventilation, max value for silica dust 150 mg/m^3)

✓ Not employing workers unsuitable to work and employing them elsewhere suitable,

✓ Quartz (SiO_2) content of the material should be detected and necessary plans should be prepared for working procedures and thus workers' health conditions should be made clear.

✓ Ideal working methods should be applied, and suitable masks and safety glasses should be used by workers employed in environments exceeding certain concentration limits

✓ Workers should have information about health risks and suitable working conditions

✓ Medical examination of workers should be made on periodical basis (physical examination, standard graphy, respiration function test)

✓ Information about cancer prevention should be given through training programs on balanced and sufficient nutrition, exercise, adequate sleep, non-smoking, coping with stress

✓ Suitable personal protection and hygiene should be provided

✓ Necessary notification should be made in case of suspicion for professional disease

✓ SiO_2 level in workplaces should be determined and people living in this kind of areas should be transferred

✓ Precautions to be taken in medical geology field will reduce mortality rate due to lung cancer.

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