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 in some polymorphic forms such as crystalline silica, alpha quartz, beta quartz, tridymite, cristobalite, keatite, coeite, 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 Yildiz, 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 Stocset 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 a 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 21st 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$_2$,
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 (İnan, 2001; Roushdy-Hammad, 2001; Carbone et al., 2007). Çermik-village in Diyarbakır, Büyüktatlı town in Afsin 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 Petrik 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 respirable 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, preventative 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 structures receive different amounts of chemical elements in different ways. Some major elements like SiO₂ 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 (Gökдумan, 2009).

Workers in Asian countries are also exposed to silicium extracted from rocks with silica content in Iran. Workers in socioeconomic group with low relation of procedures in this document (Çalışma ve Sosyal Güvenlik Bakanlığı Asbestle Çalışmalarda Sağlık ve Güvenlik Önlemleri Hakkında Yönetmelik) (ÇSGB (Minister of Labor Health and Social Security) (2003) ÇSGB (Minister of Labor Health and Social Security) (2003)).

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 SiO₂ content should be inspected by company executives, and workers should be informed about this matter. Rock and cancer risks and suitable working conditions

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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/m³)
- Not employing workers unsuitable to work and employing them elsewhere suitable,
- Quartz (SiO₂) 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
- SiO₂ 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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