Yerbilimleri, 22 (2000), 149-161
Hacettepe Üniversitesi Yerbilimleri Uygulama ve Araştırma Merkezi Bülteni
Bulletin of Earth Sciences Application and Research Centre of Hacettepe University

Environmental health problems related to mineral dusts in Ankara and Eskişehir, Turkey

Ankara ve Eskişehir yörelerinin mineral tozlarıyla ilgili çevre sağlığı sorunları

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ABSTRACT

A high frequency of malignant pleural mesothelioma (MPM), a high frequency of calcified pleural plaques (CPP) and pleural thickening (PT) have been observed in Turkey. The cause of these diseases and their relationships and mechanism of mineral dust are still under debate, and there are contraversies. The purpose of this study is to try to correlate potentially hazardous minerals and explain distribution of MPM, CPP, and PT in Ankara (Ilgaz, Çankırı, and Elmadağ) and Eskişehir (Mıhallıççık, Sorkun and Çardak). Potentially hazardous minerals and their source rocks, the potential synergy between the different pathogenic mineral dusts were evaluated together with intensity of exposure and type, duration, and fiber dimension within the study areas. While the lifetime exposure to a high dose of short and thin mineral fibers including chrysotile, tremolite and antigorite in Çankırı; and chrysotile, tremolite, antigorite, and anthophyllite in Eskişehir with their repeated episodes of injury may be the cause of the MPM; low dose, short and long, but thick , splintery tremolite fibers seem to be the cause of the CPP and PT in Ilgaz and Elmadağ of Ankara. Serpentinite, amphibolite, metahornblendite, and metapyroxenite are the sources for these fibers.

Key words: Ankara, Eskişehir, mineral dust, CPP, MPM, PT

ÖZ

Malign plevral mezotelyoma (akciğer zarı kanseri) (MPM), kalsifiye plevral plak (CPP) ve plevral kalınlaşma (PT) Türkiye'de yaygın olarak görülür. Bu hastalıkların nedenleri ve mineral tozları ile ilişkileri dünyada hala tartışma konusudur ve çelişkilidir. Bu çalışmanın amacı; Ankara (Ilgaz, Çankırı ve Elmadağ) ve Eskişehir (Mıhallıççık, Sorkun ve Çardak) yörelerinde sağlığa zararlı minerallerin türleri, kaynak kayaçları, boyutları, mineral tozlarına maruz kalınan süre, hastalık türleri ve oranları birlikte değerlendilerek belirtilen hastalıklarla mineral tozlarının ilişkisini saptamaktır. Sonuç olarak, yaşam boyu ince ve kısa krizotil, tremolit ve antigorit lifleri Çankırıda; yaşam boyu ince ve kısa krizotil, tremolit, antigorit ve antofillit liflerinin Eskişehir yörelerinde MPM nedeni olabileceği saptanmıştır. Ilgaz ve Elmadağ yörelerinde görülen CPP ve PT nedeni ise, asbestiform olmayan, ancak yapay olarak yöre halkı tarafından kullanım için toz haline getirilen düşük dozda, kalın ve uzun ve kısa tremolitlerdir. Yukarıda bahsedilen sağlığa zararlı minerallerin kaynağı serpentinit, amfibolit, metahornblendit ve metapiroksenittir.

Anahtar kelimeler: *Ankara, Eskişehir, mineral tozları, CPP, MPM, PT*

INTRODUCTION

A data set of medical studies related with malignant pleural mesothelioma (MPM), calcified pleural plaques (CPP), and pleural thickening (PT) from Anatolia, Turkey have been reported. Hacettepe Medical School alone collected 255 cases of MPM and higher number of CPP and PT in Anatolia, Turkey in 1980 (Barış, 1987). Table 1 indicates the number of cases reported (first numbers) and the number of patients (second numbers) examined from the areas investigated. The number of cases reported by Barış (1987) in Hacıhasan of Ilgaz, and Şabanözü, Gümerdiğin, Gürpınar and Çapar of Çankırı, Ankara; by Karakoca et al. (1997) and Keyf et al., (1994) in Edige of Elmadağ, Ankara; and by Barış et al. (1987) in Mihallıççık of Eskişehir. Airborne fibrous mineral dusts were observed both outdoors and indoors, originating from air and soil. Therefore, the people living in these areas have been exposed to these fibrous minerals since their birth. The question of carcinogenic potential and other types of pulmonary diseases, such as CPP and PT of chrysotile, and amphibole asbestos are not only of scientific interest, but also have legal, public policy, and public health importance.

Despite extensive cancer studies in human, certain controversies remain about asbestos exposure and human cancer. The key questions concern whether or not, and to what extent, exposure to chrysotile asbestos, including its natural contaminant tremolite, causes mesothelioma in human. Thus the primary controversy is the question of fiber type in causation of mesothelioma. 'Amphibole hypothesis', officially introduced in 1990 (Mossman et al., 1990), stating that chrysotile asbestos is not potent cause of malignant peritonal mesothelioma supporting Environmental Protection Agency of USA (EPA) (1986) and Doll and Peto (1985). The amphibole hypothesis has raised many crucial issues and served to focus research on still partially unanswered question of why different exposed populations have experienced such different rates of major asbestos diseases.

Stayner et al. (1996), Cullen (1996), and Mcdonald et.al. (1997) also suggested that chrysotile may be less potent than some amphibole asbestos minerals in causing mesothelioma. Some of the recent publications, however, suggested that chrysotile asbestos is the main cause of pleural mesothelioma in humans (i.e., Huncharek, 1994; Nicholson and Landrigan, 1994).

At least from a diagnostic perspective, asbestos has another curious effect; it can cause pleural lesions, visible some decades after exposure (Selikoff and Lee, 1978). Pleural plaques are the most common of these lesions in the central Anatolia and in the other parts of the world. Calcified or noncalcified plaques are seen almost exclusively in persons exposed to asbestos. Since these lesions are much more common in central Anatolia than malignant tumors, their occurrence might be one way of

Table 1. Number and distribution of MPM, CPP and PCC in the study areas (see text for explanation).
Çizelge 1.*Çalışma alanlarında MPM, CPP, and PT değerleri ve dağılımları* (ayrıntılı bilgi metin *içerisindedir).*

	Type of diseases related with mineral dust
ILGAZ (Ilgaz-Hacıhasan)	CPP: 32/100 PT: 35/160 MPM: 0/160
ÇANKIRI (Şabanözü, Gürpınar, Gümerdiğin and Çapar)	CPP+PT: 3/310 MPM: 13/310
ELMADAĞ (Edige)	CPP: 32/176 PT: 27/176 MPM: 0/197
ESKİŞEHİR (Mihallıççık, Sorkun and Çardak)	CPP: 470/4238 MPM: 6 cases

measuring impact of asbestos on the general population. The purpose of this study is to examine the evidence concerning the importance of asbestos in causing MPM, CPP and PT in Ilgaz (Hacıhasan), Çankırı (Şabanözü, Gürpınar, Gümerdiğin, and Çapar), and Elmadağ (Edige) areas in the Ankara region and Mihallıççık, Sorkun, and Çardak areas in the Eskişehir region.

MATERIAL AND METHODS

Ultramafic and mafic rocks are the sources for the hazardous minerals. These rocks are used by the villagers as garden walls, bricks, natural insulation material for housing, white stucco plastered their walls, to filter grape molasses, and baby powder. Although they are closed down in 1981 in the Çankırı area, there are asbestos mines about 1-2 km away from the villages such as Şabanözü (Çankırı) and Mihallıççık (Eskişehir). Therefore, occupational exposure to mineral dust is inevitable in these areas. Another exposure type is through water: rainwater, percolating through the soil, washes out fine fibers that many of them are fine enough to be respirable, and lofted once slurry is dried.

Ultramafic and mafic rocks were studied for fiber type risk comparison to find out the link between mineral dust, hence source, and the diseases in the areas. Field studies include sampling and environmental investigation of the residental areas. Samples were collected from bedrock, source rock, and wherever necessary for the soil, insulation materials, wall plasters and other materials used, and some tissues. Total of 180 samples of source rocks, and 3 samples from the each material used (soil, insulation material and white stucco) for every residental areas were collected. Fibers were differentiated utilizing fiber morphology, chemical composition, and diffraction patterns by using optical and electron microscopes, X-ray diffraction spectro-metre (XRD), and atomic absorption spectro-metre (AAS). Electron microscope studies were done at the University of Iowa, USA. STEM (scanning transmission) mode of TEM (transmission electron microscope) at 100 Kv were used for the tissue samples. The XRD analyses were done at the Hacettepe University and the General Directorate of Mineral Research and Exploration (MTA) laboratories. Water samples from the Ilgaz area were analyzed for particals and metal concentrations. Element concentrations were analyzed by AAS at the Hydrogeology laboratories of the Hacettepe University. Human tissue and airfilter analyses from the literature were also taken into account for the results.

GEOLOGICAL SETTING

Ilgaz–Çankırı-Elmadağ area (Figure 1) is located within the Ankara Melange which is the broad term to describe the rocks defined as an olistostromal and tectonic mixture of ophiolitic material and sediments of oceanic origin with exotic blocks including pelagic sediments, radiolarian chert, dunite, harzburgite, pyroxenite, gabbro, and basalt (Bailey and Mc Callien, 1950, Akyürek et al., 1980, 1984; Norman,1985). The Ankara region has two superimposed suture zones of disparate ages comprising imbricate belts of Late Triassic (Karakaya Complex) and Cretaceous (Anatolian Complex) napes (Koçyiğit, 1991). In many areas, the outcrops of the Ankara Melange are located along the Izmir-Ankara suture, where they are truncated by faults defining the suture. Okay (1998) suggested that İzmir-Ankara suture represents the Paleo-Tethyan as well as the Neo-Tethyan suture. Kozur (1998), suggested that the Triassic oceanic development ended in the middle or late Norian, and therefore, the age of the İzmir-Ankara Zone is late Norian.

In descending tectonic sequence three main melange units (Koçyiğit, 1991), dominated by different clast assemblages (Çapan 1981; Akyürek et al.,1984; Norman, 1984), are recognized in the Ankara Melange. These assemblages are 1) Upper Karakaya nappe; 2) Lower Karakaya Nappe; and 3) the Anatolian Nappe. The Karakaya Complex tectonically lies over a Hercynian crystaline basement with Carboniferous isotopic ages (Okay, 1998). Çankırı and Ilgaz area are both located within the Kılıçlar section of the Anatolian Nappe. Eskişehir region is widely excepted as the part of the Cretaceous ophiolite located at the western most end of the Ankara Melange (Figure 2). Kulaksız (1977) recogized two different metamorphic units which were called Northern and Southern Metamorphics in Eskişehir area within melange unit. Mihalıççık, Sorkun and Çardak are situated in the Northern Metamorphics consists of metabasites with relict minerals, metaharzburgite-serpentinite, pyroxenite, dunite and hornblendite.

MINERALOGY AND PETROGRAPHY OF THE SOURCE ROCKS

Due to tectonism, low grade metamorphism, hydrothermal alteration and weathering of the rocks affected the secondary mineralization in the areas studied. The Chemical Alteration Index of (CIA= 100 x (Al_2O_3/ (Al_2O_3+ CaO^t+ Na_2O +K_2O)) (Nesbitt and Young, 1982,1984, and 1989; Nesbitt and Wilson, 1992) values of mafic rocks calculated from the available data of the published literature (i.e., Kulaksız, 1977; Tankut and Sayın, 1990; Tankut and Gorton, 1990), varies from 0.39x100 to 0.70x100 indication of intermediate chemical alteration in the study area. In general, the intensity of chemical weathering is reflected in the mineral alteration. Heavy fracturing also increases the alteration rate, hence amount of secondary aluminous phases. Minerals of the source rocks and other marerials such as soil, wall plaster and air samples are tabulated in Table 2 for comparison.

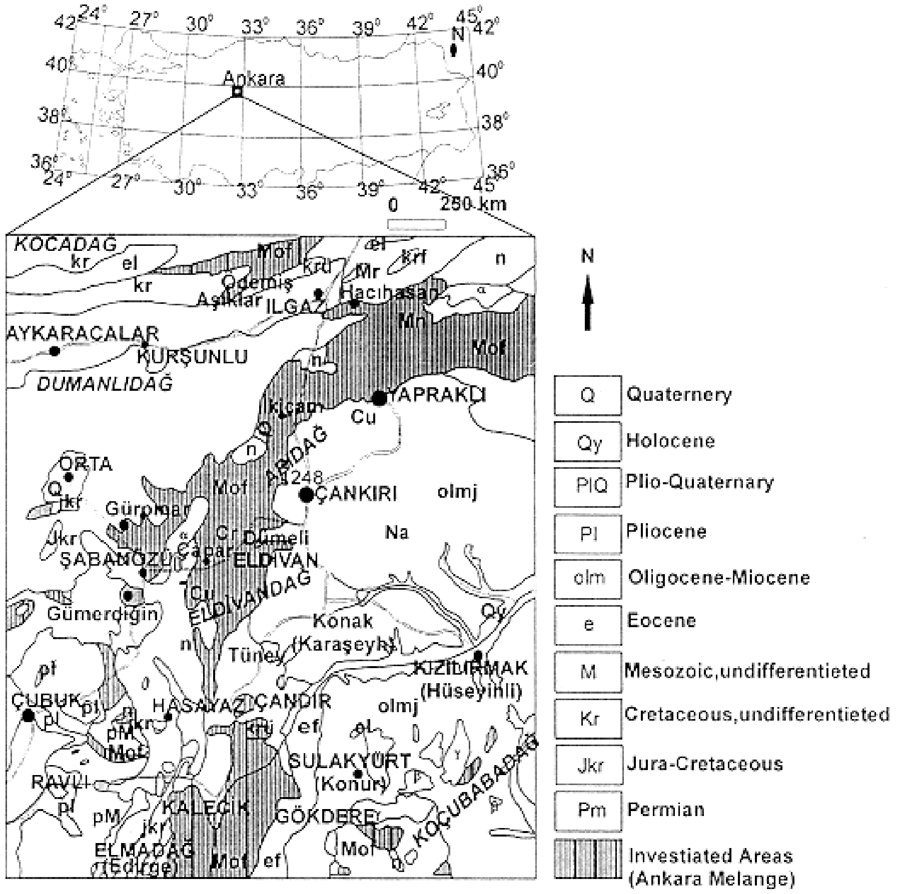

Figure 1: Geological map of the study area in the Ankara region (revized from 1/500 000 scale map of MTA)
Şekil 1: Ankara yöresinde çalışılan alanın jeoloji haritası (1/500 000 ölçekli MTA haritasından revize edilmiştir)

Commercially avaliable ore-grade asbestos deposits derived from harzburgite type peridotite (Gümerdiğin, and Çapar). The area was heavily fractured and three different episodes of fracture systems were observed during the field studies. All three serpentine minerals chrysotile, lizardite, and antigorite with an approximate composition $H_4Mg_3Si_2O_9$ and tremolite, chlorite, talc, magnesite, brucite, sphene, and calcite are found as secondary minerals in the ultramafic rock samples of the area (see Table 2). Presence of serpentine, tremolite, brucite, and chlorite are the characteristic minerals of ultramafic rocks in the low grade metamorphism. Chrysotile is the main asbestos type with tremolite contamination. Field and microscopic studies indicated that the fibers were formed at the

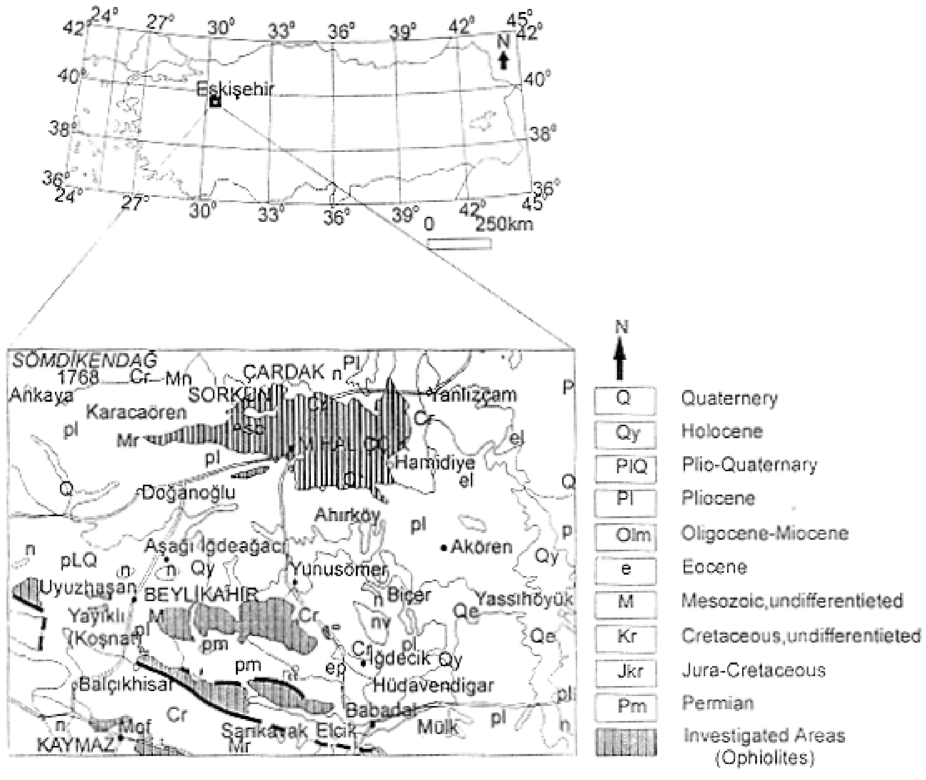

Figure 2: Geological map of the study area in the Eskişehir region (revized from 1/500 000 scale map of MTA)
Şekil 2: Eskişehir yöresinde çalışılan alanın jeoloji haritası (1/500 000 ölçekli MTA haritasından revize edilmiştir)

same time as the matrix serpentine rock from the parent material and also later placing existing matrix material, starting at fractures and fissures growing inwards. The fibers are usually aligned approximatelly across veins. Their length may reach to 3-4 cm. There is also widespread non-commercial occurrences of chrysotile as parts of the extensively altered bodies of serpentinite. Lizardite occurs in finegrained aggregates. Antigorite is present in the main matrix together with chrysotile and also occurs as lenticular veins and along faults and shear planes with talc. Occurences of magnesite, talc, and antigorite may be ascribed to shearing movements assisted by penetration of hydrothermal fluids in the Çankırı area. Occurences of antigorite may also be the product of progresive metamorphism.

There are chrysotile asbestos deposits in Mihallıççık, Sorkun and Çardak in the Eskişehir region. Mineralogical differences of the asbestos deposits are observed in the Ankara and Eskisehir regions. The ultramafic tectonites consist of olivine, orthopyroxene, clinopyroxene, and chrome-spinel in the Eskişehir area. Cumulate ultramafics comprise olivine, clino-pyroxene, orthopyroxene, and plagioclase. Secondary minerals include lizardite, chrysolite, antigorite, actinolite-tremolite, talc, chlorite, sphene, magnetite, and carbonate. Chromite is also present as accessory mineral. Secondary products may comprise up to 90% of the samples. Tremolite, actinolite, and chlorite are the characteristic minerals in low grade regional metamorphism indicating greenschist metamorphism. There are another rock associations with tremolite, anthophyllite, talc, chlorite, and relict pyroxene in the same area. These mineral associations are presented in the Table 2. Anthophyllite $(Mg, Fe)_7(Si_8O_{22})(OH, F)_2$ is present with an asbestiform habit. The presence of asbestiform anthophyllite and the other minerals such as tremolite, and talc may be indication of regional metamorphism of ultra-basic rocks associated with amphibolite metamorphism. Field and mineralogical studies indicate the mixture of both thin and thick, and long and short fibers of chrysotile, tremolite, and anthophyllite as potentially hazardous minerals in the Eskişehir region.

In the Ilgaz area, carbonate rocks make up the base rocks. Mafic and ultramafic rocks are only in the form of small exotic blocks. They are mainly hornblendite metamorphosed into the amphibolite facies and located away from the town, but are used as insulation material. Tremolite, hornblende, edenite, talc, chlorite, and rutile are the characteristic minerals present in the amphibolite facies of the ultramafics in the Ilgaz samples (see Table 2). Hastingsite and eckermannite are also detected as a tracer amount . The amphibole group minerals exhibit an extremely wide range of chemical composition in the area. The amphibole structure admits great flexibility of ionic replacement. Edenite $(NaCa_2Mg_5Si_7AlO_{22}(OH)_2)$ can be regarded as derived from tremolite $(Ca_2Mg_5Si_8O_{22}(OH)_2)$ by the addition of Na in the A site and the substitution of Al for Si indicating progressive metamorphism. Common hornblende and edenite can be termed as hornblende. Eckermannite $(Na_3Mg_4AlSi_8O_{22}(OH)_2)$ is also related to tremolite by complete replacement of Ca_2 by Na_2, and this is compensated by the replacement of Mg_3Al_2 for Mg_5. This replacement may indicate the chemical changes in the later stage by increasing in Na and Al content in the study area. Tremolite seem to be the only hazardous mineral among these and is the mainly of fragment type.

Edige of Elmadağ area is covered by vegetation and soil. Source for the wall plaster and insulation material used is transported from nearby outcrops. The source rock is low-grade regionally metamorphosed (greenschist facies) ultrabasic rock mainly consisting pyroxenite. The main characteristic minerals are tremolite, talc, and chlorite (see Table 2). Anthophyllite and riebeckite are present as tracers. Montmorillonite and stevensite, which are interlayering of montmorillonite and saponite, are present as weathering products.

MINERALOGY OF SOIL, MATERIAL USED, TISSUE, AND AIR DUST

Airborne fibrous mineral dusts were observed both outdoors and indoors, originating from the air and soil. Therefore, the people living in these areas have been exposed to these fibrous minerals since birth. Most of the bedrock used as garden walls and bricks for housing are heavily altered and include fibrous health hazard minerals. Table 2 shows the minerals of the insulation material, wall plaster and also some tissue samples from each area.

Table 2: Sources and types of minerals in the study areas

Çizelge 2: Çalışma alanlarından alınan örneklerin mineral dağılımları ve kaynakları

	Type of the Source Rock	Metamorphism and Alteration Minerals of the Rock	Minerals of Soil	Minerals of the Insulation Material	Minerals of the Stucco	Minerals of Air Filter	Minerals Found in the Tissue Samples
Çankırı	Ultramafic rocks (harzburgites, pyroxenites and dunite) with characteristics of green schist facies	Chrysotile Lizardite Antigorite Tremolite Magnesite Sphene Chlorite Talc Brucite Calcite	Chrysotile Tremolite Talc Chlorite		Chrysotile Tremolite Eckermannite Quartz Feldspar Mica		Tremolite Silica Chlorite
Eskişehir	Ultramafic rocks (harzburgites, pyroxenites and dunite) with characteristics of green schist facies	Chrysotile Lizardite Antigorite Actinolite-tremolite Magnesite Sphene Chromite Talc Chlorite Carbonate	Chrysotile Tremolite Actinolite Anthophyllite Talc Chlorite				
	Ultramafic rocks (harzburgites, pyroxenites and dunite) with characteristics of amphibolite facies	Tremolite Anthophyllite Talc Chlorite					
Ilgaz	Hornblendite (with characteristics of amphibolite facies)	Tremolite Hornblende Edenite Hastingisite (trace) Eckermannite (trace) Rutile Talc Chlorite	Tremolite Talc Chlorite	Tremolite Mica Chlorite		Tremolite Eckermannite Rutil Mica Chlorite Calcite	
Elmadağ	Pyroxenite (with characteristics of greenschist facies)	Tremolite Talc Chlorite Montmorillonite Stevensite	Tremolite Anthophyllite (trace) Riebeckite (trace) Talc	Tremolite Talc Chlorite	Tremolite Talc Chlorite		

The general vegetation in the villages of Çankırı and Eskişehir areas were sparse due to the serpentinite soil and the low annual rainfall which provides an unfavorable environment for plant growth. Combinations of climate, the relative sparseness of the vegetation cover, and fine grain size of the pervasive minerals, due to heavy fracturing, make these uniquely erodable natural sources of fibres. There are asbestos mines about 1-2 km from the villages. However, asbestos expoliation has been ceased in the area. White stucco is used as natural insulation material and to paint most of the houses. The white stucco and the material used for grape molasses and baby powder in the region contained tremolite, eckermannite, quartz, feldspar, and mica. Mineralogical examination of lung tissues showed 2 x 10^5 ferruginous bodies and 3 x 10^5 tremolite fibers per gram of dried tissue (Barış, 1987). Silica and diatome particles were also observed in large numbers in the tissue samples. In the Çankırı area, air filter analyses revealed about 5 f/ml and the mean fiber length was 3.5 μm. Some of the fibers are about 20 μm in length (Table 3). STEM micrograph of tissue sample shows the tremolite fiber (Figure 3). Beside the asbestos mines, there are some asbestos mill and factories in the town centre of Mihallıççık, and nearby Sorkun and Çardak. Many of them were open asbestos mines extracted with spades and shovels. Chromium, sepiolite, kaoline, and marble workshops, mills and factories also contribute to occurrence of heavy dust in the area. The soil analyses indicates the presence of chrysotile, tremolite, anthophyllite, talc, and chlorite.

In the Ilgaz area, the annual rainfall is higher than that in the Çankırı area and the area is covered by forests. Although the bedrock is carbonate, including limestone and dolomite, there are exotic blocks of the melange which are also used for multiple purposes by the local people. Most of the houses were made from wood and mud brick, and the walls were plastered with mud. The white stucco to paint the wall is rarely used. However, the insulation material is made out of natural material collected from the earth. Tremolite, chlorite, and mica were observed in the natural material used as insulation. There was no mining activity in the nearby villages. Amphibole group minerals, which occurred in these regionally metamorphosed ultrabasic exotic blocks, included tremolite, hornblende, edenite, hastingsite, and eckermannite. Talc, calcite, quartz, chlorite, muscovite, rutil, and clay minerals were observed in the soil samples. Analysis of airborne dust particles indicate the presence of tremolite, eckermannite, calcite, chlorite, mica, and rutile. The fibers are mostly shorter than 3.5 μm in length. Water samples were analyzed to determine fiber and element concentrations. Analyses indicated that water was very soft (pH = 8.13) and drinkable and the concentrations of heavy metals were below the detection limits. Numerous asbestiform fibers were observed in water samples. Tremolite was the predominant amphibole group mineral observed in the area. Trace amounts of anthophyllite and riebeckite in the soil of the Edige area was observed. It is difficult to determine whether a specific amphibole fiber is the result of the fragmentation of precursor asbestiform amphibole or a "common" prismatic and stubby amphibole. However, the mean aspect ratios of asbestiform amphiboles tend to be 20:1 or greater in fibers longer than 5 μm. The study of air dust and tremolite from the source rock in the Ilgaz and Elmadağ areas indicates that the average aspect ratio of tremolite fiber is 15:1. Therefore, the common natural amphibole group minerals of the Ilgaz (Hacıhasan) and Elmadağ (Edige) areas are mainly non-asbestos; but upon fracture through the clevage planes of the larger grains they could produce abundant smaller fibers. Natural mineral dust, therefore, was a composite of primary mineral fibers and also fibers formed both by secondary chemical reactions and artifical processes introduced by human activity in the area.

DISCUSSIONS AND CONCLUSIONS

As shown on Table 1, distributions of chest diseases reported in the Çankırı and Eskişehir areas are similar. In these areas, MPM is observed beside PT and CPP. There is not any reported cases of MPM in the literature, but only PT and CPP were observed in the Ilgaz and Elmadağ areas. Vast amount of fibers are produced by the erosion of natural deposits at the surface of the soil due to heavy fracturing, poor vegetation, and climatic conditions in the Çankırı and Eskişehir areas. Rural exposure was enhanced by various human activities including agriculture and exposure to indoor sources such as white stucco, wall paint, insulation material, and mining. Beside dose, type and concentrations of the fibers, duration of exposure and morphology of the fibers may

Table 3: Type of hazardous minerals, their distrubutions, doses, diameters and lengths
Çizelge 3: Çalışma alanlarının sağlığa zararlı mineralleri ve bunların dağılımları, dozları, uzunlukları ve kalınlıkları

	Type of asbestos minerals	Fiber length	Fiber diameter	Fiber dose (indoor)
ILGAZ (Hacıhasan)	Tremolite	~20-200µm	~1-20 µm	Not analyzed
ÇANKIRI (Şabanözü, Gürpınar, Gümerdiğin and Çapar)	Chrysotile, tremolite, and antigorite	~4-20 µm	~0.2-0.3 µm	2.9-7fiber/ml
ELMADAĞ (Edige)	Tremolite	~10-200µm	~2 µ -20 µm	0.054-0.1 fiber/ml
ESKİŞEHİR (Mihalliçik, Sorkun and Çardak)	Chrysotile, tremolite, antigorite anthophyllite	~2µ-30 µm	~0.2-0.5 µm	Not analyzed

be associated with the cancer cases. Answers to those questions will help to explain the disease patterns. Table 3 represents the type of asbestos minerals, their source rocks, fiber length, fiber diameter, and dose for comparison. Field reconnaissance and mineralogical studies show high amounts of chrysolite, tremolite, and some antigorite fibers in the Şabanözü, Gürpınar, Gümerdiğin, and Çaparkayı villages in the Çankırı area. High doses of chrysotile, tremolite, antigorite, and anthophyllite are present in Mihallıççık, Sorkun, and Çardak of the Eskişehir area. The fibers are short and thin in both Çankırı and Eskişehir areas. Although, only tremolite fibers observed in the tissue samples in the Çankırı area, heavy dose, but short and thin fibers of exposure of chrysotile are inevitable. Chrysotile is known to split apart longitudinally and dissolve in the lung, whereas amphibole remain in the lungs for years without significant dissolution (Wagner et al., 1982 and 1986; Sebastian et al., 1989). For laboratory experiments, it has hypothetical that a chrysotile fiber of 1µm in diameter would completely dissolve in the human lung in 9±4.5 months (Hume and Rimstidt, 1992). It is very difficult to observe chrysotile fibers of the tissue samples under optical microscope because of the small size. It is also very difficult to observe through electron microscope due to beam sensitivity of chrysotile. These may be the reasons stated above that chrysotile fibers were not observed in the tissue samples in the Çankırı area. A large series of studies using intrapleural or intraperitonal injection had demonstrated that long and thin fibers were the most effective at producing mesotheliomas, once they were within the body cavities (Pott et al., 1972; Stanton and Wreinch, 1972; Pott et al., 1974; Stanton et al., 1977). Fibers longer than 20 µm are more potent than fibers shorter than 10 µm with respect to the induction of pulmonary tumors and fibrosis by inhalation (Davis et al., 1986b; Davis, 1989). A recent study by Dodson et al. (1997) confirmed that the most dangerous fibers were more than 8 µm in length and less than 0.25 µm in diameters. However, both the chrysotile and amphibole fibers in the pleura/plaques of all of these studies have been reported as consistently shorter than those in the parenchyma itself. Repeated episodes of cells tissue injury followed by proliferation and genetic damage may give rise to a tumor that proliferates autonomously (Antoniades, 1992). Wagner et al. (1980) and Davis et al. (1986a) also have amplified the importance of the numbers of very fine fibers for determination of chrysotile pathogenecity. Therefore, the suggestion of the authors is that the life time, high dose exposure to short fibers of chrysolite, tremolite, antigorite and/or anthophyllite and their release of toxic oxygen free radicals may be the cause of the malignant mesothelioma in the Ankara and Eskişehir regions.

Asbestiform minerals are not always found with a fibrous habit. Tremolite, for example, occurs naturally in three distinct morphological forms or mineral habits. It may occur as asbestos, splintery fibres or in massive crystalline deposits. Any mechanical manipulation of asbestos rocks rapidly produces many long, thin fibres/fibrils, since for the most part, asbestos fibrils are easily separable. This, in

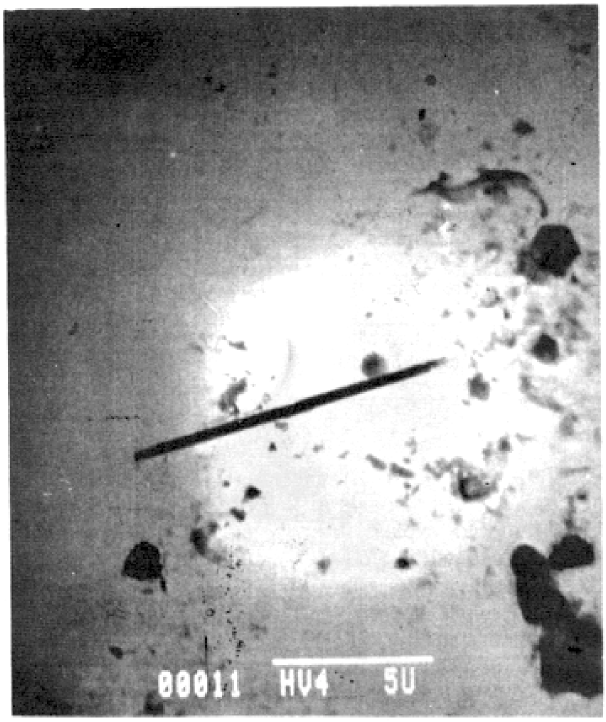

Figure 3: STEM micrograph of tissue sample showing the tremolite fiber (accelerating voltage is 100 KV)
Şekil 3: Dokudan alınan örnekte tremolit lifini gösteren STEM mikrografı (voltaj 100 KV'tur)

part, because of translocation along a twin plane, which produces a much reduced cohesion. Other defects in the structure are thought to contribute to this property. A lot of data has accumulated which suggests that amphibole asbestos, and its non-asbestos analoques, possess very different biological potential. Davis et al. (1991) demonstrated that although asbestiform tremolite was extermely carcinogenic when injected into the peritoneal cavities of rats, non-asbestiform tremolite samples had little or no carcinogenic potential. These observations suggest that the tremolite contamination of any material may present a concern only if thin asbestiform fibers are present. Therefore, it is important to distinguish betweeen asbestiform and non-asbestiform tremolite. Churg (1996) provided data as evidence that amphibole fibers did reach and accumulate in the parietal pleura in localized "hot spots", and that some of these fibers were relatively long. Plaques appeared at much lower total fiber concentrations than did asbestosis. Churg (1996) also suggested that localized inflammatory reactions were probably important in the genesis of plaques. Hence, this study may imply that the long, thick and low dosage of splintry tremolite fibers may be the cause of the pleural plaques and the thickening of the villagers living in the study area. Although they are in very low dose, an additive factor of other pathogenic active minerals, such as trace amount of riebeckite and antophyllite, may include the inflammatory or hypersensitivity reactions, and than splintery tremolite may cause the plaque accumulation in the area.

In countries such as Turkey with high levels of durable fibers in the environment, either as a result of natural comminution of rocks, mining or other activities-building with fiber-rich stone or painting houses with fiber-rich stucco, considerable environmental exposure is inevitable unless particular care is taken. If this is not done, then the cumulative fiber doses experienced by the exposed population will be associated with an increased in mortality.

Acknowledgments

The authors acknowledge to Emeritus Prof. Dr. İzzettin Yusuf Barış of Depatment of Chest Diseases, Hacettepe University, Turkey.

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