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Monitoring of airborne asbestos fiber concentrations in high traffic areas of Isfahan, Iran in summer 2015

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ABSTRACT

Aims: This research was conducted to measure the concentration of asbestos fibers in the ambient air of high traffic areas of Isfahan and to evaluate their spatio-temporal variation during summer 2015.
Materials and Methods: Air samples were collected from eleven points covering traffic areas of the Isfahan city including Enghelab square, Azadi square, Bozorgmehr bridge, Ghods square, Ahmedabad square, Artesh square, Emam Hossein square, Nazar junction, Vafaei junction, Felezzi bridge, and Tayyeb fork during 3 months of summer 2015. Scanning electron microscope (SEM) coupled to an energy dispersive X-ray system was utilized to count and identify the asbestos fibers.
Results: Seasonal average concentration of airborne asbestos fibers in the studied region was 10.04 ± 4.90 SEM f/l. The results of this study showed that the highest concentration of asbestos fibers was measured in Azadi square (18.08 ± 3.863 SEM f/l) and that the lowest was found in Nazar junction (3.92 ± 1.749 SEM f/l). There was a significant correlation between the concentration of asbestos fibers and atmospheric temperature and humidity ($P < 0.05$). The mean concentration in September was higher than August and July (11.08 ± 4.66).
Conclusion: Heavy traffic in the dense areas of the city, and topographical and meteorological features of the city have a major contribution in asbestos fiber emission which resulted in its exceeded levels from the WHO guideline (2.2 SEM f/l). Therefore, effective strategies such as traffic management, industrial movement, and products replacement can be effective in reducing airborne asbestoses fibers concentrations.

Key words: Ambient air, asbestos fibers, Isfahan

INTRODUCTION

Asbestos is one of the solid pollutants that may present within the air particles.[1] Asbestos refers to a group of fibrous silicate minerals that is of great significance due to health and economic effects. These minerals are divided into two groups: Serpentine (chrysotile) and amphibole (amosite, thermolite,

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actinolite, anthophyllite, and crocidolite).[2] Chrysotile (white asbestos) is the major type of asbestos composed of SiO_4 layer structure, tetrahydride, and octahydrate.[3] Chrysotile asbestos is spiral, thin, flexible, and longer than other types of asbestos. Despite the fact that chrysotile has a logical definition of minerals, amphibole fibers have different physiochemical properties.[4] Amphiboles are usually identified based on their main compounds, for example, iron magnesium amphibole (amosite), calcium amphibole (thermolite), and alkaline amphibole (crocidolite).[5] The diameter of amphibole fibers is usually greater than that of chrysotile and thus are somehow stronger yet less flexible. For example, chrysotile fibers have a diameter of 0.03–0.06 μ, whereas crocidolite fibers are 0.07–1 μ in diameter.[6] Crocidolite fibers are the most dangerous type of asbestos. They are dry and stretched that can be embedded in bronchi, eventually transferred to the tissue of lung and pleural hole[7] amosite, commonly used in construction products, is more toxic than chrysotile yet is smaller and straighter.[8] Asbestos texture might emit to the air when using compounds containing asbestos, destruction activities, repair and maintenance of buildings or houses, and repair, and breaking the process of vehicles.

When the asbestos fibers are inhaled, they can be trapped inside lungs and remain there for many years.[9] Diseases developed under the influence of asbestos might emerge themselves after 10–35 years following the first exposure.[7] Over time, this fiber can accumulate in the body organs and result in serious diseases such as asbestosis, mesothelioma, lung cancer, and other pulmonary problems including pleural plaques, thickening of the membrane surrounding the lungs, and pleural effusion.[10,11] Asbestos is known as a carcinogen of A1 group.[12] Although all forms of commercial asbestos are carcinogenic, their chemical composition is different.[13] As many as 55 asbestos-related malignant mesothelioma, in 2005, have been observed in the annual report of cancer cases in Iran.[2] Todays, application of asbestos is seriously controlled by strict regulations and due to confirmation of its health hazards, 40 countries have removed it entirely from their products. According to the Act of Environmental protection organization, consumption of asbestos has been banned in Iran since 20 July 2007.[14] Application of asbestos fiber is commonplace due to its desired properties.[10] Wide usage of asbestos in Iran first began in 1329, when in the middle 1349s, it was abundantly used thanks to inexpensiveness and desirable quality in heat-resistant products, clothes with a tensile friction, electricity, sound insulation, and products resistant to chemical and biological compounds.[2] In industry, asbestos fiber is employed as a strengthening agent, consolidator, and to prevent abrasion and burning in the preparation of a wide variety of pipe sheets, brake pads, clutch pads, washers, and insulation.[10]

One of the main and important sources of asbestos fiber emission into the air of cities is brake and clutch pads in vehicles.[2,15] Chrysotile fiber almost accounts for 30–60% of the major compound of clutch disc.[16] Vehicles, whether light or heavy, emit considerable amounts of asbestos fiber into air due to the high friction between asbestos-containing brake pad and the wheel tray and the abrasion occurring onto the brake pad.[17] The American environmental protection organization has estimated that annually 32 million kg of asbestos is admitted into the environment in response to the abrasion of brake pads.[18] When asbestos fibers emit into the air, due to their aerodynamic characteristics, they have the potential to travel very long distances. Since no chemical decomposition takes place in fibers and washing by rainfall and snow is the only mechanism for removing them, these fibers constitute a small portion of all fiber-like aerosols present in the ambient air.[19,20]

Isfahan is one of a large high populated and industrialized city located in the heart of Iran. Vehicular traffic and industrial activities resulted in the city to be second polluted city of Iran after Tehran. So that the presence of asbestos fibers in the ambient air, especially in the air of dense and crowded area might be undeniable. As there is no data showing the asbestos fiber types and concentration in the outdoor air of the city, monitoring of its level is necessary for emission control and public health protection purposes. Although concerns on adverse health effects of exposure to high concentrations of asbestos fiber are raised, there is inadequate information about their levels in the ambient air. This research carried out to monitor airborne asbestos fiber concentration in the ambient air of high traffic areas of Isfahan and to evaluate their spatio-temporal variation during summer 2015. The effects of meteorological parameters on their concentration were also investigated.

MATERIALS AND METHODS

This is a cross-sectional study conducted in the 3 months of summer 2015. Eleven sampling point were chosen based on the urban traffic and deployment of emission sources by considering the geographical and meteorological parameters [Figure 1], and totally 33 samples were collected and analyzed (one sample per month from each point) These points include: Enghelab square, Azadi square, Bozorgmehr bridge, Ghods square, Ahmedabad square, Artesh square, Emam Hossein square, Nazar junction, Vafaei junction, Felezzi bridge, and Tayyeb fork. In addition, one sampling point was considered in a nontraffic area, namely in green area of students' dormitory located in the Isfahan University campus. The sampling was carried out during the day at various times in the downwind side of the location.

The air samples were taken using a low flow rate pump (SKC MCS Flite, Swedish) on membrane filters of mixed cellulose ester (MCE; pore size 0. 8 μm; diameter 25 mm) placed inside an open face filter holder (model FP050/2; Schleicher and Schuell, Dassel, Germany). The air flow rate was adjusted at 9.5 l/min, with a sampling duration of 3 h for each sample.

The sampling height was within the breathing range of 160–180 cm off the ground level.

As phase contrast microscopy method (NIOSH method 7400) used in the previous studies was unable to differentiate asbestos fibers from nonasbestos fibers, scanning electron microscopy (SEM) method was employed to count fibers on filter certify the asbestos fibers. The filters were located inside lidded plate and transferred to Razi metallurgical laboratory in Tehran for preparation and SEM analysis.[21,22]

For sample preparation, the filters were attached on the pin mounts by copper bilateral glue, put inside a sputter deposition system (EMITECH K450X, EM Technologies LTD, England) and coated with gold under vacuum to maximize electrical conductivity of the samples. An SEM (model WEGA/TESCAN, Czech Republic) was used for fiber analysis. The coated filters placed in the SEM sample holder and after running the system, adjusting the scan field under a magnification of 2000–3000, the fibers were counted and the total numbers of fibers and scanned fields were recorded for further calculation. Detection sensitivity of the SEM device lies within a range of 0.0001 fiber per millimeter. According to the method, fibers with a length of ≥ 5 μm, and a diameter of < 3 μm with a minimum length-to-diameter ratio of 3:1 were considered as asbestos. To detect the type of asbestos fibers, energy dispersive X-ray spectroscopy (EDX) coupled with the SEM was used. This method gives a spectrum showing elemental content of the fibers which can be compared with reference spectrum for fiber type identification. Calculation of the airborne asbestos fiber concentrations was done by the following formula using the SEM results:

$$C_{SEM} = (1000.\ N.\ A)/(V.\ n.\ a)$$

Where
C: Concentration of asbestos fibers in the air (f/ml)
N: Number of counted fibers
A: Effective area of the filter (the area that usually has a different color than the filter due to passage of air stream) considered as around 385 mm^2 for the 25 mm filter
V: Volume of sampled air (L)
n: Number of counted fields of images
a: Calibrated area of each image (mm^2).

RESULTS

Based on the data obtained from SEM analysis, the number of fibers in the filters and thereby, in the ambient air of the sampling points was calculated using the above-mentioned formula. Table 1 shows average concentrations of the airborne asbestos fibers at 11 sampling points, and their total monthly averages among the summer in the sampling point are presented in Table 2. According to the results, the concentration of the fibers was the highest in the Azadi square (18.08 ± 3.86 f/l) and the lowest in Nazar Junction (3.92 ± 1.75 f/l) [Table 1]. During the season, the concentration showed a gradual increase from July to September [Figure 2]. However, a seasonal average of 9.34 ± 4.90 f/l was obtained. Mean meteorological parameters for the sampling times which were obtained from the Isfahan meteorological organization are presented in Table 3. Examples of an SEM image of thermolite and crocidolite fibers and they EDX spectra are displayed in Figures 3 and 4.

Table 1: Mean concentration of asbestos fibers in the sampling points

	Sampling location	Sample number	Standard error of mean (f/l) ± standard deviation	Minimum (f/l)	Maximum (f/l)
1	Enghelab square	3	12.52 ± 1.78	10.02	16.4
2	Bozorgmehr bridge	3	08.78 ± 0.89	7.87	9.72
3	Ghods square	3	16.41 ± 1.31	14.72	17.66
4	Ahmedabad square	3	15.96 ± 2.11	15.7	16.49
5	Nazar junction	3	03.92 ± 1.75	2.92	6.56
6	Azadi square	3	18.08 ± 3.86	15.31	20.78
7	Vafaei junction	3	06.77 ± 1.88	5.83	9.11
8	Artesh square	3	07.32 ± 0.38	6.28	8.83
9	Emam Hossein square	3	11.85 ± 1.00	10.93	13.92
10	Felezzi bridge	3	05.85 ± 0.75	5.1	6.73
11	Tayyeb fork	3	06.78 ± 1.17	5.05	8.15
	Total average	33	9.34 ± 4.90	4.2	18.7

Table 2: Mean meteorological parameters at different months of the summer

Month	Sample number	Wind speed (m/s)	Temperature (°C)	Relative humidity (%)
July	11	12.3	29.6	20
August	11	6.6	27.6	21
September	11	16.1	25.2	27
Seasonal mean	33	11.6	27.4	22.6

DISCUSSION

The results presented in Table 1 show that, in all of the sampling points, the concentration of asbestos fibers were not within the allowable limits recommended by valid organizations. Topographical situation of Isfahan, which was surrounded by Karkas and Gahrood Mountains in the East and the endpoint of Chaharmahal mountainous regions in the west, trivial precipitation and weak wind speeds result in low dispersion, dilution, and autopurification of the atmosphere which cause entrapment of air pollutants over the city. In addition, due to the heavy vehicular traffic, the concentration of asbestos fibers across these areas was larger than the WHO suggested guideline (2.2 SEM f/l).

In accordance with one-sample *t*-test, the findings revealed a significant increase in the concentration of fibers in

Table 3: Correlation between measured parameter

Parameter	Asbestos concentration	Temperature	Wind speed	Air humidity
Asbestos concentration (Pearson correlation)	1	−0.950**	0.670**	0.988**
Significant (two-tailed)		0.000	0.000	0.000
n	33	33	33	33

**Correlation is significant at the 0.01 level

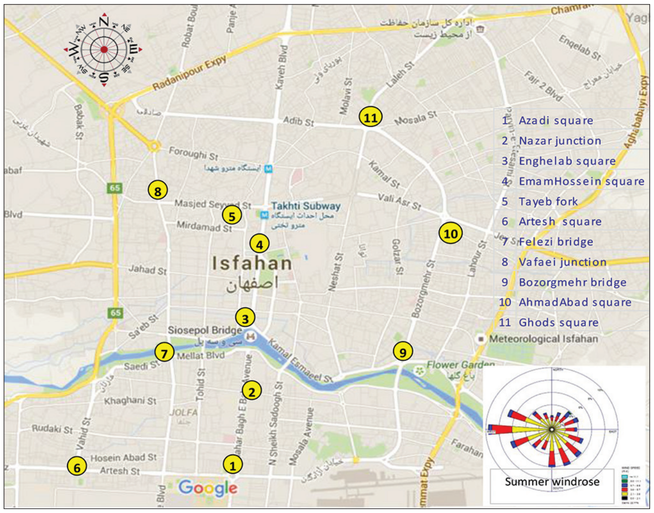

Figure 1: The map of Isfahan showing the samples collection points

September in comparison with the two other months of the summer ($P < 0.05$). This can be attributed to the heavier traffic due to the last month of summer holidays and reopening of educational centers.

Based on the results, greatest amount of asbestos fiber was related to Azadi square, where encounters with daily heavy traffic due to its positioning in the university neighborhood, proximity to the urban bus terminal, outskirt's taxes stations, and subway construction. There are lots of bus stops around the square just at the beginning of the approaching streets, so relocating the bus stops far from the square or diverting the

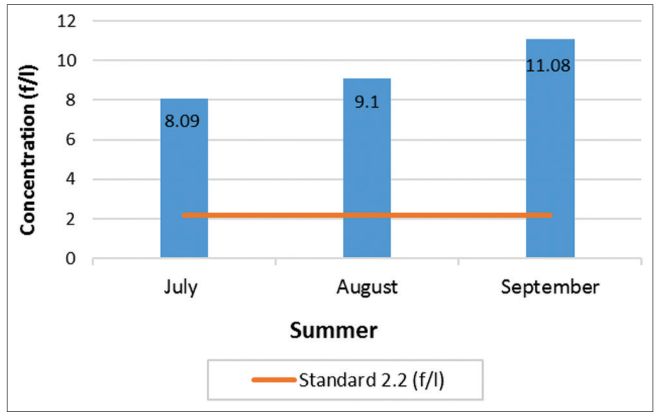

Figure 2: Mean concentration of asbestos fibers at different months of the summer and its comparison with the WHO guideline

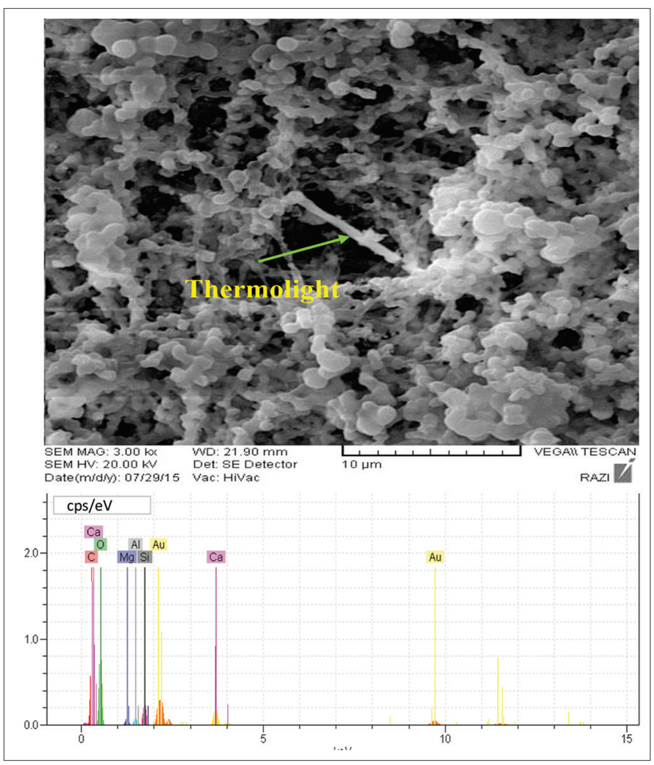

Figure 3: A scanning electron microscopy image of a thermolite fiber observed in the air sample and its energy dispersive X-ray spectrum

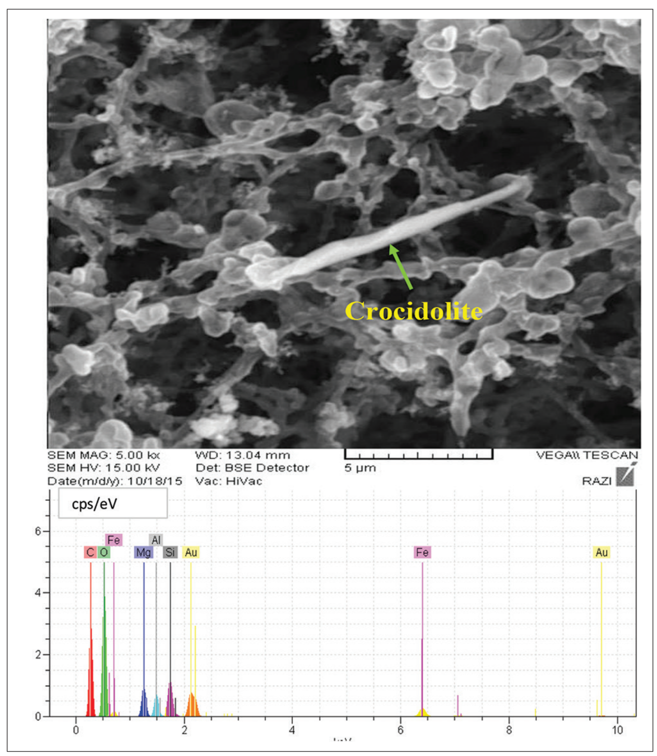

Figure 4: A scanning electron microscopy image of a crocidolite fiber observed in the air sample and its energy dispersive X-ray spectrum

city bus lines to the adjacent streets can substantially reduce the pollutant emission. Ahmadabad, Ghods, Enghelab, and Emam Hossein squares ranked the rest in terms of the fibers concentrations which was directly related to the traffic patterns in these areas. For Ahmadabad and Ghods square, one can also say that proximity to the urban bus terminal and health center result in a heavy traffic. For Enghelab and Emam Hossein square, one can refer to the spatial position of these areas in terms of commercial and touristic status, low width of streets, and subway construction cause a heavy traffic jam. Traffic, in turn, causes frequent brakes by vehicles and thus frequent abrasion of brake and clutch pad, causing further liberation of asbestos fibers. The vehicular traffic was lighter in the rest of the sampling locations.

The meteorological data including temperature, relative humidity, mean wind speed, and direction were taken from the meteorological office of Isfahan. The mean of these parameters is provided in Table 2. In accordance with statistical test (t-test), there was significant relationship between the concentration of asbestos fibers and the meteorological data ($P > 0.05$, $r < 0$) [Table 3].

In a study conducted by Kakouei in Tehran, a higher asbestos fibers concentration, larger than the standard limits, has been obtained congruent with the results of this research.[2] Whereas studies conducted in some European countries have shown very low levels of asbestos fibers in the ambient air, for example, in a study conducted in three regions across Italy, the mean concentration of asbestos fiber was obtained as 0.56 SEM f/l.[3] In another study performed by Bologna in a region close to asbestos production unit in Milan, Italy, the mean concentration of asbestos fiber was detected to be lower than 1 f/l.[23] These show that Isfahan, when compared with European countries, are around 10–18 times more at risk of the hazardous asbestos particles. In a study conducted by Fathi *et al*. in Shiraz city, the mean asbestos fiber concentrations of 11.88 f/l SEM has been reported which is close to our study.

Sample of an image taken from thermolite fiber and by SEM and its EDX spectrum are shown in Figure 4. Where it has strong peaks of Mg, Si, and Ca, with a trivial Na peak it matches well with a thermolite reference spectrum. In case iron peak is present, then sodium peak should be trivial.[22] Thermolite is often found next to along with vermiculite and chrysotile.[24]

An image of crocidolite taken from the air samples along with its EDX indicates that this fiber has a strong peak of Fe and Si. It also possesses a large clear Mg peak (the reason of its distinction from amosite). Since this fiber is smaller, the weak Na peak is not observable.[22] The profile of crocidolite asbestos contains Mg, Si, and Fe, attached to oxygen atom.[24] The crocidolite fibers are very dangerous which can be deposited in the bronchi and eventually transfer into lungs and pleural cavity.[25]

CONCLUSION

The results of this study indicate that the concentration of asbestos fibers across the high traffic areas of Isfahan is higher than the ambient air guideline suggested by the WHO. This can be due to heavy vehicular traffic in the target areas and topographical status of the city. Azadi square is the most pollutes area due to metro construction and heavy traffic. Owing to the high concentration of asbestos fibers, the health of surrounding communities, occupational groups, especially taxi drivers and traffic officers can be adversely affected. Therefore, traffic management, substitution of asbestos with safe substances in different products such as brake and clutch pads, transferring the industries that work with asbestos out and downwind side of the city, development of green spaces can help to eliminate the asbestos fiber and other pollutants emission.

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Conflicts of interest

There are no conflicts of interest.

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