Asbestos Concentrations and Lung Restrictive Patterns

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ABSTRACT: Asbestos applications were limited during past two decades in developed nations due to its debilitating health problems, while in developing countries it's various usages continues. The main goals of present study were evaluation of asbestos concentrations in ambient outdoor and indoor air and occupational exposure, as well as exposure effects on pulmonary function. Sampling procedure was carried out during May and June 2010 at four outdoor and seven indoor air sampling stations. Ten persons were selected based on their exposure limits including high, moderate and low exposure. Also to assess pulmonary function of workers, 42 spirometry cases were tested. Samples were analyzed by SEM with EDXA. Obtained results revealed that average concentrations of asbestos fibers were 1.885×10^{-5} f/mL and 0.065 f/mL in outdoor and indoor air, respectively. Occupational exposure contents were between $1.5 \times 10^{-5} - 0.2$ f/mL (based on exposure limits). Spirometry tests showed that 28% of workers had impaired lung functions. Lung restrictive pattern in workers were 2% severe, 12% moderate and 14%. Results showed pattern of fibrous particles as actinolite> termolite> chrysotile in indoor air. Generally, it is clear that there is positive meaningful relationship between more than ten occupational ages and malfunction of lungs in studied workers due to asbestos effects.

Key words: Environnent, Exposure, Indoor, Ambient, Fibre, Asbestos, SEM

INTRODUCTION

Asbestos fibrous forms have been used for many years as raw materials for the production of a large variety of materials (Pastuszka, 2009). Asbestos, naturally occurring hydrated mineral silicates (Hardy & Aust, 1995) are mainly comprised of two groups: serpentine and amphibole (Jaurand *et al.,* 1984). Serpentine is represented only by chrysotile while amphiboles include amosite, actinolite, anthophyllite, crocidolite and tremolite (ATSDR, 2001; Lippmann, 2000; Meeker *et al.,* 2001; Christiansen *et al.,* 2003; Paustenbach *et al.,* 2004). A variety of mineral fiber types, especially asbestos, have been used as commercial products for thermal or acoustic insulation (Baron, 2001). Serpentines are used in industries more common while amphiboles are more dangerous and more attributable to asbestos related-diseases (Hodgson & Darnton, 2000; Mossman *et al.,* 1990). Issues related to asbestos induced disorders caught more attention worldwide in last couple of decades (Lange, 2005). Asbestos is regarded as exceedingly dangerous because the inhalation of asbestos fibers can lead to the development of debilitating health problems. All asbestos-related diseases appear to be caused from chronic exposure; acute exposure does not seem to result in serious illness. Fiber toxicity appears to be primarily a function of fiber concentration, dimensions and durability in the lungs (Baron, 2001; Lange, 2005). It has been scientifically proven that the inhalation of asbestos fibers can cause serious lung diseases, like mesothelioma (Gualtieri *et al.,* 2009). The effects of asbestos on the human body include the asbestiform varieties of serpentine, riebeckite, grunerite, anthophyllite, tremolite and actinolite (Pastuszka, 2009; Kakooei *et al.,* 2007). Also they induce fibrosis, lung cancer (by the inhalation of asbestos fibers), mesothelioma, and probably other kinds of intestinal cancer (Mossman *et al.,* 1996; Anastasiadou & Gidarakos, 2007). While the use of asbestos has been prohibited or restricted in much of the developed world consumption is growing in Asia, Latin America and the Commonwealth of Independent States (Kazan-Allen, 2005).

MATERIALS & METHODS

This research was carried out in a cement-asbestos pipe and plate manufacturing plant that is located in southwest of Iran near Ahvaz city. Asbestos particles were collected in ambient outdoor (4 stations), indoor

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air (7 stations) and workers breathing zone for occupational exposure during May-June 2010. Personnel samples were selected based on their exposure limits including four personnel samples with directly high exposure, three samples with moderate exposure and three samples with low exposure. Also blank samples were determined to prevent any interference (NIOSH, 1994). Air sampling was performed according to the standard method for asbestos sampling the NIOSH Method 7400. All air samples were collected on open-face, 25-mm diameter, 0.45-µm pore size mixed cellulose (MCE) attached to filter cassette holder connected to a SKC personnel sampling pump at flow rate 4 l/min. The duration of personnel sampling for airborne asbestos ranged from 30 to 120 min (NIOSH, 1994). Sampling pumps were placed 1 m above ground level away from obstructions that may influence air flow (NIOSH, 1994; USEPA, 1994). Samples were placed on cassette holder exactly at the end of sampling activities and they were transported to a fixed place. Samples were analyzed by scanning electron microscopy (model XL30) with energy dispersive (SEM – EDXA) (VDI, 1991). SEM measures the surface of particles on a substrate and allows for good visualization of fiber morphology (fibers >0.2 ìm in diameter). A fiber was defined as any particle longer than 5 ìm and with a length-to-diameter ratio of 3:1(NIOSH, 1994; Kakooei *et al.,* 2009). For quality assurance 10% of the field samples were recounted (Baron, 2001). The airborne asbestos concentration is given by the formula:

$$C_{SEM} = 1000\ N.\pi.\ r^2 / V.\ n_2.a \quad \text{fibers per millilitre (f/mL)}$$
equation (1)

Where: N is the number of fibers counted; n_2 is the number of screen areas examined; r (mm) is the radius of the exposed filter area; a (mm²) is the calibrated screen area; V (liters) is the volume of air sampled.

Also, asbestos fiber concentrations that were found in the contaminated filters and the corresponding values of the upper and lower confidence limits, for a Poisoning distribution, to 95% probabilities, were estimated . Spirometric examination is the most widely used tests for pulmonary function. In order to assess the possible effects of asbestos on lung function, 42 spirometry tests were done. Analyses of spirometry tests were based on American Thoracic Society (ATS) standard (American Thoracic Society, 1991).

RESULTS & DISCUSSION

All the collected asbestos samples were analyzed by SEM and the asbestos concentrations were calculated using equation (1). The results of airborne asbestos concentrations in ambient outdoor and indoor air are provided in Table (1). Table (2) shows the results of asbestos fiber concentrations in personnel samples.

The permissible exposure limits (PEL) for asbestos is 0.2 f/cm³ of air as a time-weighted average concentration (TWA, 8-h work shift with an action level) and 0.1 f/cm³ as an hour TWA (OSHA, 1998; USEPA, 1987). The National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) is 0.1 f/mL as a TWA concentration for up to an 8-h work shift (OSHA, 1998).

As Table (1) shows maximum concentration of asbestos fiber is 3.1×10-5 (f/mL) in ambient outdoor air, that is lower than permissible exposure level (PEL). Also indoor asbestos in the air in almost all samples are lower than PEL, as the geometric mean asbestos concentrations is 0.065 (f/mL) but in some stations the asbestos concentrations are higher than PEL. Although, asbestos concentrations in indoor air are higher than ambient outdoor air. Table (2) reveals that all the workers in places with direct and high exposure of asbestos have more exposure of asbestos concentrations than PEL, such as material mixing and productions, finishing, pipeline manufacturing unit and plate production unit. But workers in other categories of asbestos expose (moderate and low) have lower exposure of asbestos concentrations.

The SEM photographs in Figs. 1, 2 and 3 were obtained by a conventional SEM instrument with a metal evaporation coating and show airborne chrysotile and actinolite fibers in the ambient air. The chemical composition of the fibers was analyzed by energy-dispersive x-ray analysis. Relative elemental concentrations can be estimated from the peak areas in the EDXA analysis of the airborne asbestos. The SEM image and EDXA spectrum of chrysotile, actinolite and tremolite is show the elemental percentage of magnesium, silicon and iron are 29.32, 58.93 and 7.04%, respectively in chrysotile fiber. For actinolite elemental percentage consist silicon (62.25), iron (28.37) and calcium (6.38) and this elemental structure for tremolite are as Mg: 21.37%, Si: 46.67% and Fe: 5.51%. Also different types and compounds of asbestos fibers collected in outdoor and indoor air and occupational exposure are tabulated in Table (3). Table (3) indicates that fibers concentrations in indoor air decreases as actinolite (66%)>tremolite (22%)> chrysotile (12%). Also, actinolite has the highest concentration in ambient outdoor air and personnel samples.

Results of 42 spirometry tests in studied workers with different asbestos exposure that there are different lung restrictive functions as normal, mild, moderate and severe. According to these tests, FVC, FEV1 and FEV1/FVC were determined for all 42 workers. It should

Table 1. Results of asbestos fiber concentrations in ambient and indoor air per fiber

Area		Number of samples	Fibers counted	Asbestos concentration (f/ml)
Ambient outdoor sampling	Min		2	6.7×10^{-6}
	Max	8	7	3.1×10^{-5}
	Mean		4	1.885×10^{-5}
Ambient indoor sampling	Min		4	1.31×10^{-5}
	Max	14	17	0.13
	Mean		8	0.065

Table 2. results of asbestos fiber concentrations in personnel samples

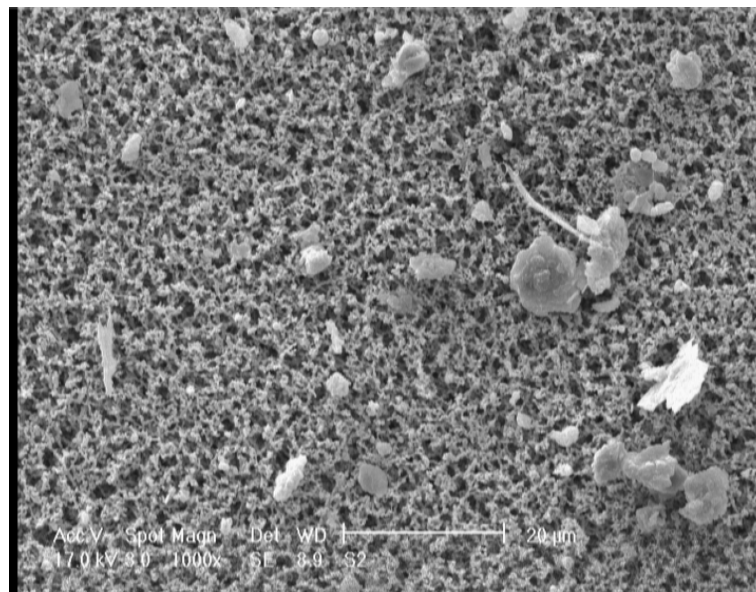| Area		*personnel* sample	Fibers counted	Asbestos concentration (f/ml)
personnel Sampling	Direct and high Expose	H1	24	0.18
		H2	18	0.2
		H3	12	0.14
		H4	16	0.15
		Mean concentration		0.17
		LCL-UCL		1.6-1.8
	Moderate Expose	M1	4	3.3×10^{-5}
		M2	6	4.5×10^{-5}
		M3	7	5.2×10^{-5}
		Mean concentration		4.3×10^{-5}
		LCL-UCL		(-0.099)-0.1003
	Low Expose	L1	3	1.5×10^{-5}
		L2	3	1.5×10^{-5}
		L3	4	3.3×10^{-5}
		Mean concentration		2.1×10^{-5}
		LCL-UCL		(-0.099)-0.1001

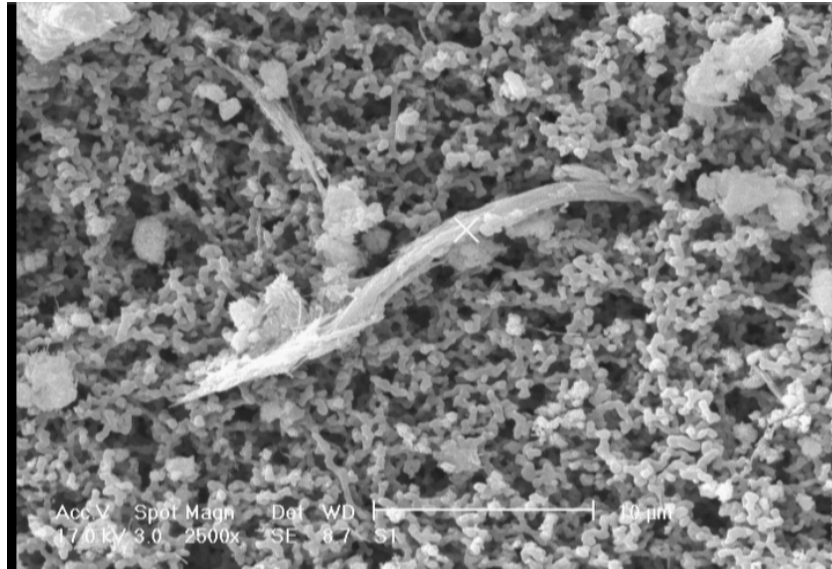**Fig. 1. Scanning electron microscope (SEM) image of chrysotile fiber (×1000)**

Fig. 2. Scanning electron microscope (SEM) image of chrysotile fiber (×2000)
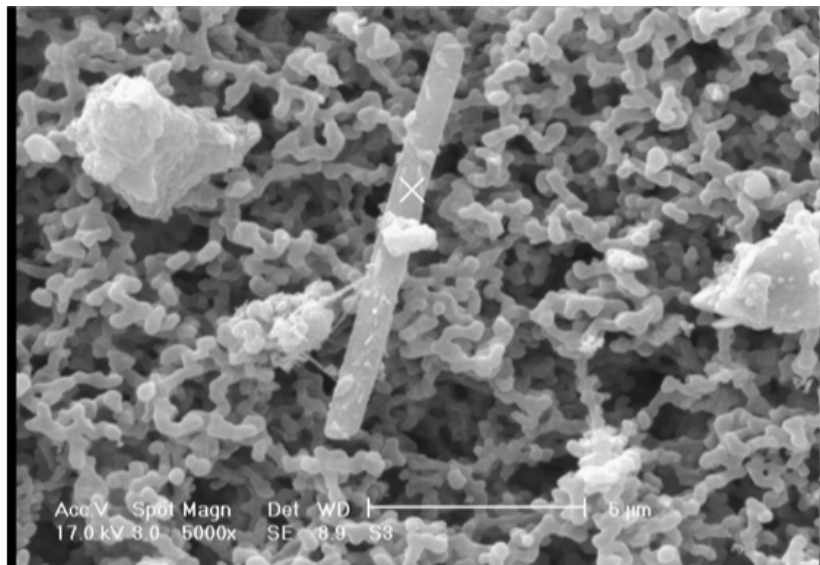

Fig. 3. Scanning electron microscope (SEM) image of actinolite fiber (×5000)

Table 3. Different types and components of asbestos fibers collected in outdoor and indoor air and ccupational exposure

Area		Fiber types	Percentage
Environmental Sampling (out door)		actinolite	100
Environmental Sampling (in door)		chrysotile	12
		tremolite	22
		actinolite	66
Personnel Sampling	High and Direct Expose	tremolite	10
		chrysotile	20
		actinolite	40
	Medium Expose	tremolite	20
	Low Expose	tremolite	10

be pointed that 28% of workers in the area of study, have abnormalities of lung function that might otherwise be overlooked and can exclude the possibility of some respiratory disorders such as chronic obstructive pulmonary disease. Abnormalities of lung function in all studied workers include different restrictive patterns such as severe (2%), moderate (12%) and mild (14%). While abnormalities percentages of lung function increase to 32% (severe4%) in some places of the studied plant with high exposure (such as material mixing and productions, finishing, pipeline manufacturing unit and plate production unit). Also, trends of lung restrictive patterns changes in workers with different asbestos concentrations exposure is presented in Fig. (4). Generally, literatures for environmental asbestos sampling are summarized in Table (4).

The reported fiber concentrations for the various sites is extremely variable ranging from practically zero in ambient environments up to 50×10^{-3}–100×10^{-3} f/mL in closed environments. Ansari et al. (2007) reported that air asbestos concentrations were about 2.00–5.09 (f/mL) in unorganized asbestos mills of Rajasthan located at Beawer, India, that is really higher than PEL. Pastuszka (2009) reported similar concentration of air asbestos in Poland and Germany (0.3×10^{-3}–1.8×10^{-3} f/mL), respectively that is more than PEL. But as Kakooei et al. reported air asbestos concentration (0.36-1.85 f/mL) in a routine brake lining manufacture in Iran is very higher than permissible limit. The present study indicates that air asbestos concentrations in some indoor stations and personnel samples with direct expose are higher than permissible limit.
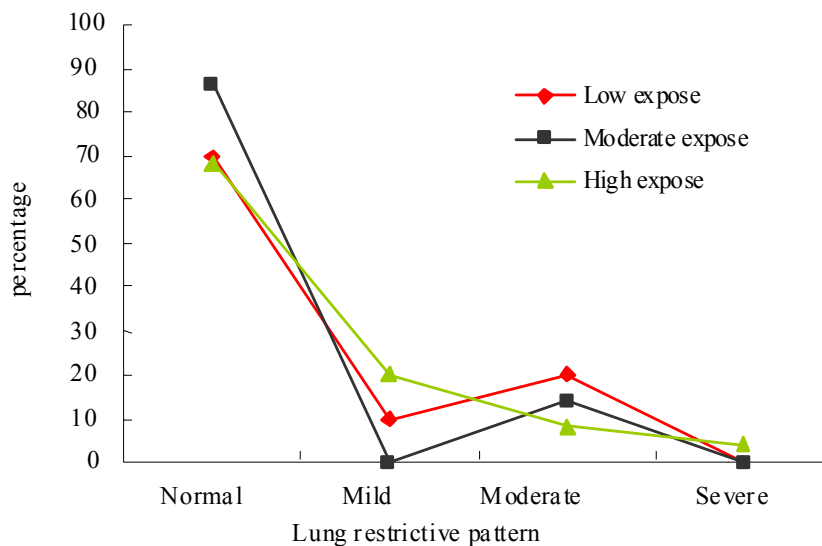

Fig. 4. Lung restrictive patterns in exposure to different concentrations of asbestos fibers (based on spirometry tests)

Table 4. Literature data on the outdoor monitoring of asbestos

Area type and Location	Concentration (f/ml)	Reference
Home environment in Upper Silesia, Poland	0.3×10^{-3}–1.8×10^{-3}	Pastuszka, 2009
Outdoor living areas nearby industrial sites, Germany	0.1×10^{-3}–18×10^{-3}	Sebastien et al., 1986
Outdoor living areas nearby a dismissed plant, Salonit Anhovo (Slovenia)	lower than 0.5×10^{-3}	Bizjak et al., 1996
Outdoor living areas nearby a dismissed plant, Szczucin (Poland)	6.2×10^{-3}	Pastuszka et al., 2000
Outdoor living areas nearby a dismissed plant, Cerdanyola (Spain)	$<1 \times 10^{-3}$	Bologna et al., 2005
Outdoor living areas nearby a plant for the production of thermo-electrical energy, Castrovillari (Italy)	0.000–1.767×10^{-3}	Cortese et al., 2006
Outdoor living areas, Biancavilla (Italy)	0.10×10^{-3}–0.56×10^{-3}	Damiani et al., 2006
Outdoor living spots nearby the asbestos ex-mining areas of Alessandria, Torino, and Cuneo, Piedmont (Italy)	0.1×10^{-3}–0.2×10^{-3}	Giacomelli et al., 2006
Unorganized asbestos mills of Rajasthan located at Beawer, India	2.00–5.09	Ansari et al., 2007
Railways rolling stock insulation removal plant in Catona, Reggio Calabria	0.1×10^{-3}-2.8×10^{-3}	Falcone et al., 2005
Routine Brake Lining Manufacture, Iran	0.36-1.85 (mean)	Kakooei et al., 2007

CONCLUSION

Base on gained results, geometric mean concentration of asbestos in ambient air (1.885×10^{-5}) is lower than NIOSH PEL (0.1 f/mL). Also indoor air asbestos concentrations are higher than permissible limit in some cases. While the workers who are in places with direct and high exposure of asbestos receive higher exposure of asbestos such as material mixing and productions, finishing, pipeline manufacturing and plate production unit. Accordingly 28% of workers have abnormalities of lung function in the area of study. Also, Abnormalities of lung function in all studied workers include different restrictive patterns such as severe (2%), moderate (12%) and mild (14%). The relationships between work ages and lung malfunction are positive meaningful ($p < 0.05$) as in worker with occupational records more than 10 years, abnormalities of lung function as restrictive pattern are very common. This mentions that process flow and machinery must be improved and adequate engineering controls such as local exhaust ventilation hoods on the process or complete understanding of proper safe work practices could be applied.

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