PREDICTION OF CANCER MORTALITY BY EVALUATION OF ASBESTOS FIBERS CONCENTRATIONS IN AN ASBESTOS-CEMENT PRODUCTS FACTORY

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ABSTRACT
Although the asbestos application is band in most developed countries but it is still used in many developing countries, escalating the mortality rate due to cancer among the workers exposed to asbestos fibers. In the present work, occupational exposure to airborne asbestos fibers in production line of an asbestos-cement products manufacturing factory were assessed, using OSHA method ID-160. For this purpose, 106 personal air samples were collected from breathing zones of workers in various processes of the factory. Cancer-related mortalities were also predicted by extrapolation of OSHA risk assessment data to the data obtained from the factory in question. The results revealed that physically disturbing processes such as mills, drilling and cutting are the most deadly processes. It was also shown that mills have the highest mortality rate due to asbestos fibers exposure, expecting 1198 deaths per 100,000 workers after one year exposure and 14665 deaths per 100,000 workers after 20 years occupational exposure. Relative risk (RR) of lung cancer after 1, 20 and 45 years working in the factory in question versus public community of Iran would be 11.6, 206.5 and 324, respectively. Cancer-related mortality predicted for dry cutting process was more than wet cutting process(RR=3.6). Finally it was recommended that job rotation and isolation of high risk operations could lead to lower cancer-related mortality due to occupational exposure to asbestos airborne fibers.

Key words: Asbestos, Mortality, Lung cancer, Mesothelioma, Gastrointestinal

INTRODUCTION
Asbestos is defined as the fibrous form of mineral silicates belonging to the serpentine and amphibole groups of rock-forming minerals, including actinolite, amosite (brown asbestos), anthophyllite, chrysotile (white asbestos), crocidolite (blue asbestos), tremolite, and a mixture containing one or more of these (Ulvestad *et al*., 2002). Inhalation of asbestos fibres is known to cause four main respiratory diseases. These include two kinds of cancer—mesothelioma and lung cancer—and two non-malignant conditions—asbestosis and diffuse pleural thickening (Darnton *et al*., 2006). Workers with occupational asbestos exposures could be experiencing up to 25% excess mortality from asbestos-related diseases (Selikoff *et al*., 1979).
Currently, mesothelioma is highly lethal with an overall median survival of 10 months (range 6-14 months) shown in a recent study (Kokturk *et al*., 2005). Approximately 80% of mesothelioma cases had past asbestos exposure(Chang *et al*., 2006). Wagner presented the first piece of evidence implicating asbestos in the pathogenesis of mesothelioma in a study of South African miners in 1960 (Chang *et al*., 2006).
The background incidence of mesothelioma, which was one to two per million per year, has increased as a result of industrial and commercial

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use of asbestos (McDonald, 1985; Spirtas *et al*., 1986; McDonald and McDonald, 1996). A high incidence of mesothelioma (20–60 cases per million) has been reported in areas with heavy shipbuilding activity(Connelly *et al*., 1987; Damhuis and Van Gelder, 1993). In industrialized countries with heavy asbestos usage from 1940s to 1970s, the annual incidence of mesothelioma in the 1990s was 2 per million in women and 10–30 per million in men in the 1980s (Chang *et al*., 2006). In the 1990s, the average annual incidence was 22 per million in the UK(Chang *et al*., 2006), and 9 per million in the USA(Antman, 1993), with age-adjusted incidence rates in the USA around 4 per million for women and 20 per million for men (Price and Ware, 2004). In Europe, the incidence of mesothelioma is also rising from 5000 dying in 1998 to a projected 9000 men dying by the year 2018, with the highest incidence in the cohort of men born from 1945 to 1950 (Chang *et al*., 2006). The incidence of mesothelioma was estimated to peak in the period between 2010 and 2020(Walker *et al*., 1983).

Corrado Magnani *et al*.,(1989) carried out a research on mortality from lung cancer due to asbestos in an asbestos cement manufacturing town in Italy. He reported that 227 deaths from lung cancer were included (184 men and 43 women). Among the asbestos cement workers mortalities were 234.0×100000 person-years among men and 35.5 among women (Magnani and Leporati 1998). Examination of the inter-study dose response relationship for the amphibole fibers suggests a non-linear relationship for all three cancer endpoints (pleural and peritoneal mesotheliomas, and lung cancer).

The peritoneal mesothelioma risk is proportional to the square of cumulative exposure, lung cancer risk lies between a linear and square relationship and pleural mesothelioma seems to rise less than linearly with cumulative dose(Rogers and Major, 2002). Mortality was studied among a group of 328 employees of an Ontario asbestos-cement factory who had been hired before 1960 and who had been employed for a minimum of nine years. The group of 87 men who had worked in the rock wool/fiber glass operations, or who had been otherwise minimally exposed to asbestos, had mortality rates similar to those of the general Ontario population, while the group of asbestos-exposed employees had all-cause mortality rates double those of the Ontario population, mortality rates due to malignancies five times higher than expected, and deaths attributed to lung cancer eight times more frequent than expected. According to the best evidence available, 10 of 58 deaths among the production workers were due to malignant mesothelioma and 20 to lung cancer (Finkelstein, 1982).

The method most commonly used to evaluate the airborne fiber concentration is the membrane filter method. The fibers are sampled on a filter and if identification is unnecessary they are counted by means of phase contrast optical microscopy (PCOM). The fibers counted are generally those longer than 5 μm with a width of <3 μm and a length to width ratio of >3:1. Counting fibers over a certain length not only reduces the variability due to the limitations of the optical microscope, but also takes into account the fact that the longest fibers appear to be the most dangerous(Grzebyk,*et al*., 2005) .

In OSHA's 1986 risk assessment, OSHA estimated cancer mortality for workers exposed to asbestos at various cumulative exposures (i.e., combining exposure concentration and duration of exposure time). MSHA (Mine Safety and Health Administration) has reproduced this data and reveals that the estimated mortality from asbestos-related cancer decreases significantly by lowering exposure (Mine Safety and Health Administration, 2008).

MATERIALS AND METHODS

The factory where the study was conducted was established in 1958 and now it is located in Iran. The factory covers an area of 180,000 square meters. Its buildings cover 34,000 square meters. A total number of 700 workers occupy the factory (350 at the production lines and 350 at the other sections). Asbestos cement pipes, roofing boards and vinyl tiles are the main productions of the factory. The factory produces 47,000 tones of boards and 40,000 tones of pipes per year. The asbestos-cement tubes manufactured in this factory contain 15- 20% asbestos and 80-85% cement.

In present study, methods recommended for sampling and analysis of asbestos by different institutions including, OSHA, NIOSH, ASTM and AIA were compared and OSHA ID-160 method was selected. The personal air samples were collected on 25 mm membrane filters. Open face holder with cowl was used to prevent the filters from accidental pollution and electrostatic effect. Personal samples were collected using low volume personal sampling pumps (model C from SKC Company, UK). A Zeiss microscope equipped with phase contrast and a computer monitor was used to analyze the samples. According to OSHA-1997 method, Walton-becket-622 graticules were used for fibers longer than 5 µm with a width of <3 µm and a length to diameter ratio (L/D) of 3:1, while Porton graticules were used for fibers with L/D of 5:1. Samples were clarified using acetone vapor with an SKC Acetone Vaporizer. All pumps were calibrated using a rotameter prior to each daily sampling. The size of each graticule was measured prior to analysis using micro meter ruler. The local representative of Zeiss Company calibrated the microscope and its monitor. The samples were analyzed using OSHA ID-160 method(Crane, 1997).

In this study the OSHA's risk assessment on asbestos- related cancer mortality was extrapolated to the data gathered from occupational exposure to asbestos. Personal air samples were gathered in different positions of production line. The production halls were divided into four zones according to the type of processes. These zones included:

Zone 1 : Raw material mills(sheet and tube), Hacheck machine, Perdorit machine, mold making .

Zone 2 : 5 meter tube cutting, 5 meter tube material making, Man shone cutting, man shone Lathing.

Zone 3 : cutting(dry and wet), drilling, sheet residual cutting, sheet and cotton stock .

Zone 4 : residual mill.

Totally 106 personal air samples were collected from breathing zones of workers in different sections of production processes, using OSHA ID-160 method. 9 samples could not be clarified, because of excessive dust so they were omitted from the study. Sampling flow rate and sampling time were about 1.5 L/min and 30 minutes, respectively, according to acceptable fiber load. The samples were collected in different working shifts to represent the most real condition.

RESULTS

Table 1 demonstrates the results of personal air sampling from breathing zone at different sections of production line.

The comprehensive research conducted by OSHA can be a reliable tool for risk assessments in similar situations. Extrapolation of OSHA cancer risk assessment for asbestos occupational exposure was used in present study to estimate the cancer related mortality in this asbestos product manufacturing factory.

Fig. 1 depicts the predicted mortality rate (per

Table 1: Air sampling from breathing zone at different sections of production line

Section	Position of sampling	Number of samples	Total sampling time (min)	f/cc (3:1<L/D)	
				Mean	SD
Zone 1	Raw material mills	14	630	8.2	0.36
	Hacheck machine	14	520	1.3	0.47
	Perdorit machine	10	360	1.3	0.1
	mold making	6	180	0.85	0.07
Zone 2	5 meter tube cutting	7	210	6.2	0.57
	5 meter tube material making	6	225	0.8	0.28
	man shone Lathing	7	315	4.4	0.42
	Wet man shone cutting	2	60	1.3	0
Zone 3	Dry cutting	7	315	4.35	0.5
	Wet cutting	4	120	1.2	0.02
	Drilling	3	90	4.1	0.01
	Sheet residual cutting	4	65	4.5	0.13
	Sheet and cotton stock	2	60	1.8	0
Zone 4	Residual mill	10	225	7.03	2.21

100,000 persons) due to cancer after a year being exposed to the occupational exposure levels of asbestos measured in different parts of the factory. This figure. shows that raw material mills with air borne concentration of 8.2 asbestos f/cc potentially causing 1198 death (per 100,000 persons) after one-year exposure, is the most harmful process. Residual mills with air borne concentration of 7.03 asbestos f/cc have a mortality rate of 1027 death (per 100,000 person) after one-year exposure are the second harmful processes in the factory.

Fig. 2 depicts the predicted mortality rate (per 100,000 persons) due to cancer after 20 years being exposed to the occupational exposure levels of asbestos measured in different parts of the factory in question. The results reveal that 14665 workers will die (out of 100,000 workers) 20 years after being occupationally exposed to the air borne asbestos concentrations measured in Raw material mills. It means that 14.7% of workers that are involved in this process will experience deadly asbestos related cancers after 20 years being exposed. Similarly for 12.6% of operators in Residual mills, the previous outcome would be in prospect.

Fig. 3 demonstrates the predicted mortality rates (per 100,000 persons) due to cancer from asbestos fibers after 45 years being exposed to the occupational exposure levels of asbestos measured in different parts of the factory in question.

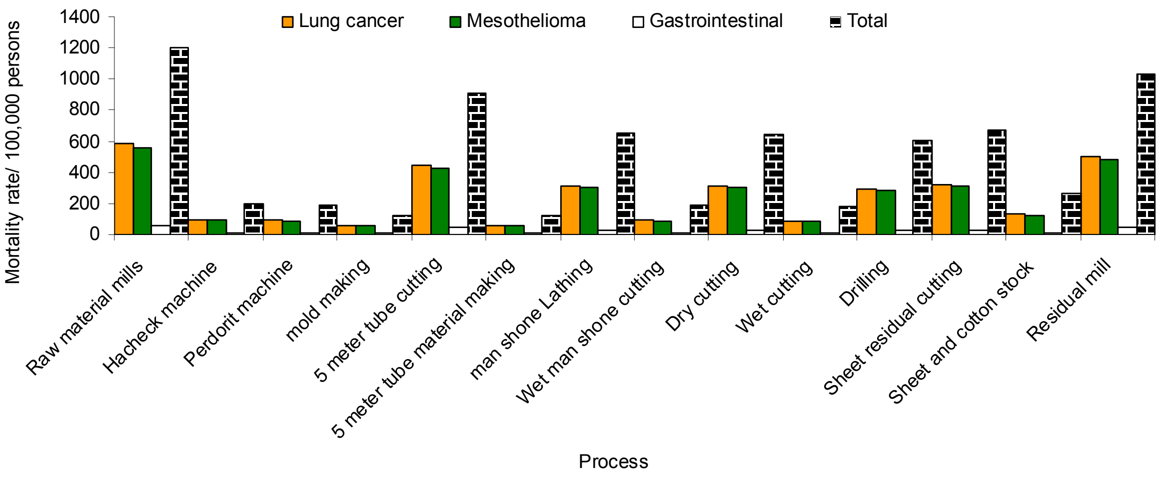

Fig.1: Cancer-related mortality per 100,000 after one year occupational exposure to asbestos in different processes

In Figs. 5 to 7 it is supposed that all of the workers are exposed to the average concentration of asbestos fibers. Figs. 5, 6 and 7 respectively show the predicted mortality rate (per 100,000 persons) due to cancer after 1, 20 and 45 years being exposed to the average occupational exposure levels of asbestos measured in different parts of the factory in question.

DISCUSSION

The average mortality rates predicted in present study (Fig. 5) are similar to the results obtained by Corrado Magnani *et al* (1989). They reported a mortality rate of 234 per 100,000 people – year for men due to lung cancer while it is predicted to be 243 per 100,000 people – year in the present study (Magnani and Leporati, 1998).

According to Fig. 4, in a very conservative judgment, if the workers are exposed to the average concentration of asbestos fibers measured in whole factory, the mortality rate due to mesothelioma will be 232 per 100,000 people after one year exposure. This mortality rate is 2320 to 1160 times higher than incidence rate due to background concentration of asbestos fibers (0.1 to 0.2 mesothelioma per 100,000) reported by McDonald *et al*. (McDonald *et al*. 1996). This mortality rate is even 116 to 38.6 times higher than the incidence rate in areas with heavy shipbuilding activity(Connelly *et al*. 1987; Damhuis and van Gelder, 1993).

Fig.7 illustrates that as the exposure time increases, the mortality rate due to lung cancer increases more rapidly than mesothelioma and gastrointestinal cancers. The predicted mortality rates shows that if all workers are exposed to the average concentration of asbestos fibers measured in this factory, 1.75 deaths are expected after one year exposure (Fig. 4). This incident rate will be 24.4 deaths after 20 years exposure time (Fig. 5).

On the other hand, according to WHO, cancer

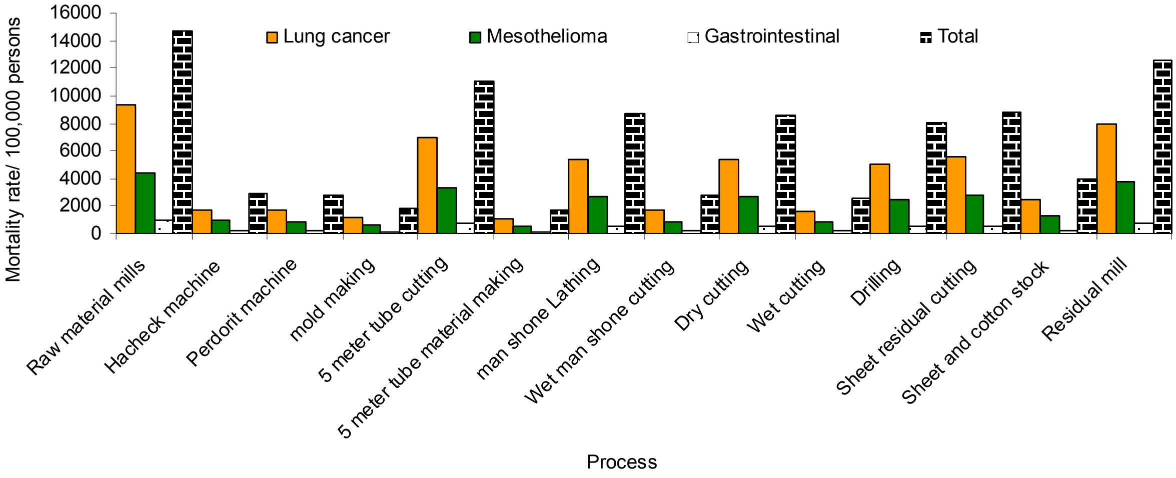

Fig. 2: Cancer-related mortality per 100,000 after 20 years occupational exposure to asbestos in different processes

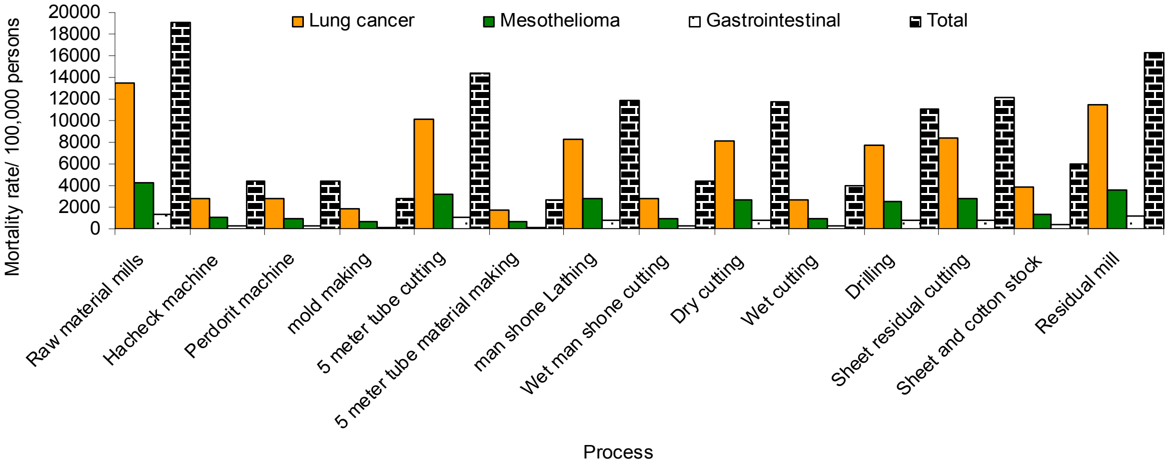

Fig. 3: Cancer-related mortality per 100,000 after 45 years occupational exposure to asbestos in different processes

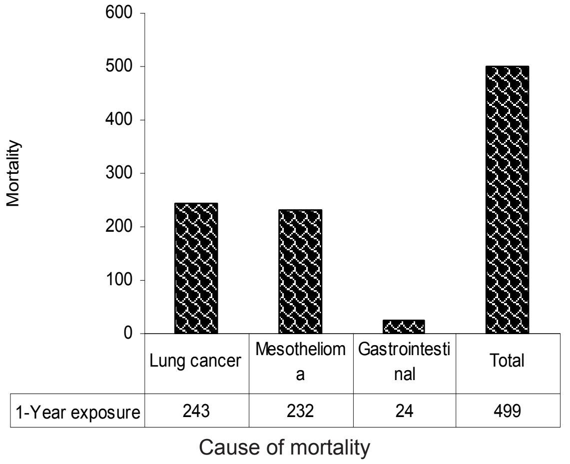

Fig. 4: Cancer-related mortality per 100,000 after 1 year occupational exposure to average concentration of asbestos in the whole factory

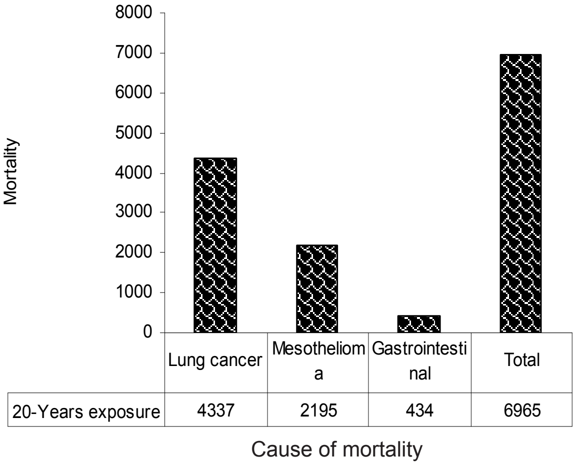

Fig. 5: Cancer-related mortality per 100,000 after 20 years occupational exposure to average concentration of asbestos in the whole factory

is the forth cause of mortality (%12) in Iran in 2005. On the basis of WHO's statistics in 2005, incidence of lung cancer in Iran was 21 per 100000 in 2005 for public community. Relative risk (RR) of lung cancer after 1, 20 and 45 years working in the factory in question versus public community of Iran would be 11.6, 206.5 and 324, respectively (WHO, 2008).

The results revealed that the milling, cutting and drilling processes emit the most noticeable amount of airborne asbestos fibers (Table 1). This is mainly due to the nature of physical agitation in these processes. Modification of these processes or application of effective engineering controls to them is the major step to be considered in order to achieve an acceptable indoor air quality in such factories.

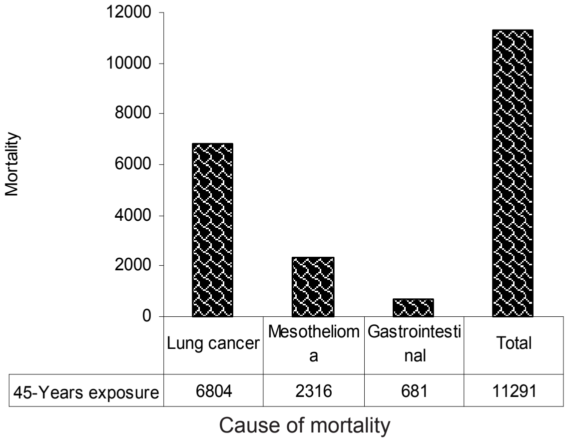

Fig. 6: Cancer-related mortality per 100,000 after 45 years occupational exposure to average concentration of asbestos in the whole factory

The comparison of wet cutting with dry cutting process shows that substituting dry cutting process with wet cutting process can reduce the mortality rate from 645 to 178 deaths per 100,000 people after one year being exposed to the occupational exposure levels measured in this factory (RR=3.6). The same results can be expected from substituting wet milling and drilling with the same dry processes.

However, isolation as a valuable efficient measure with prevention of the distribution of airborne pollutants from active emitting sources such as mills and cutting machines through other less harmful processes can decrease the cancer-related mortality in such catastrophic situations. Personal protective equipments and training of employee can be helpful to attenuate the deadly outcome of occupational exposure to airborne asbestos fibers.

The studies on cancer related mortality of

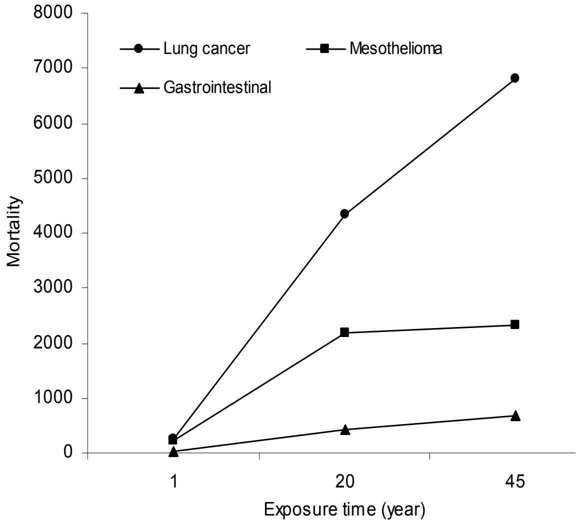

Fig. 7: The comparison of predicted mortality rates /100,000 persons of workers being exposed to the average asbestos concentration measured in factory under study

asbestos are usually epidemiological studies conducted long after exposure. Such studies are not able to show the exposure level and consequently the relationship between asbestos exposure level and its harmfulness. Therefore, a sort of instrumentation that being able to indicate the average exposure dose level to the asbestos fibers are required to show the real relationship between exposure dose and the mortality rate. This can be the basis of studies in the future.

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