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Occupational exposure to crystalline silica (quartz) and prevalence of lung diseases in Dhand Killi, Mohmand Agency, northern Pakistan

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ABSTRACT: *Occupational exposure to respirable crystalline silica (quartz) has long been known to produce fatal lung diseases specifically silicosis and pulmonary tuberculosis. To address this issue a cohort analysis of occupational exposure, relation to crystalline silica (quartz), the mortality and morbidity rate of various lung diseases were carried out among silica miners and millers in Dhand Killi Mohmand Agency, northern Pakistan. The exposure level of respirable silica (quartz) in the indoor environment counts from 1-14 mg/m^3 per 1 hour, which is thousand fold higher as compared to internationally recommended exposure limits (0.05 mg/m^3) over time-weighted average of 8 hours. The mortality and morbidity rate of silica related lung diseases were found potentially high among the silica (quartz) miners and millers during the follow up period (1996 to 2004) in the target area. The overall analytical data illustrates that the cohort cases of occupational exposure to respirable silica (quartz) and silica related fatal diseases is remarkably high.*

INTRODUCTION

Crystalline silica (quartz) is the name given to a group of minerals composed of silicon and oxygen, the two most abundant elements in the Earth's crust. The most common form of naturally occurring crystalline silica is alpha or low form of quartz (Virta, 1993). The principal use is in the manufacturing of glass and ceramics, molds for casting iron, aluminum, and copper alloys, abrasives, such as sandpaper, grinding and polishing agents, and sandblasting materials. Other common uses are in toothpaste, scouring powders, metal polishes, paints, rubber, paper, plastics, wood fillers, cements, and road surfacing materials. Silica flour is also used in foundry applications.

Though as a known commercial mineral as mentioned above, the occupational exposure to respirable crystalline silica (quartz) dust in work place has also some adverse health effects as well. The leading silica-related diseases of concern are silicosis, accelerated silicosis, acute silicosis (silica-induced alveolar proteinosis), silicotuberculosis, silica-associated lung cancer, systemic sclerosis and chronic airflow obstruction (Roseman, 1996; Cowie, 1994; Steenland et al., 1995; Weill & Macdonald 1996; Donaldson & Borm, 1998). Most, if not all of the several hundred epidemiological studies of exposure to quartz dust are of occupational cohorts.

Crystalline silica occurs in small metamorphosed veins and acidic pegmatites in different locations of Mohmand, Malakand Agencies and District Charsadddda (Ali, 1964; Bakr, 1965). All these deposits are being mined and used in various products especially in glass and ceramics industry. During this

study it was observed that silica workers are highly exposed to silica dust during mining and milling. The worst examples are the quartz crushing and milling units located at Dhand Kili, Mohmand Agency. No studies have been conducted till to date to identify the toxicity and fibrogenic characteristics and the environmental health hazards posed by the respirable crystalline silica dust in Pakistan. This study was designed for the first time to ascertain the toxic and fibrogenic characteristics including composition, crystalline isomorph, and exposure level of respirable silica dust particles emitted during mining and milling and their health hazards among miners and miller in Dhand Killi, Mohmand Agency.

METHODOLOGY

Twelve samples including rock and air were collected from silica (quartz) mines and milling units located at Dhand Kili Mohmand Agency. The air samples include respirable particulates ranging from $PM_{10, 7,5,2 \text{ and } <1}$ μm were collected using high volume sampler with various sizes filters. Short-term air samples of one hour were collected due to the excessive dust released during milling.

The representative rock and air samples were analyzed using by using atomic absorption spectrometer and X-ray diffrectometer in the NCe in Geology, University of Peshawar. These analyses were performed to determine the fibrogenic characteristics including the chemical and mineralogical composition, crystalline isomorphs and the exposure level to airborne silica in the area.

Detailed survey was conducted to identify the mortality and morbidity rate of silica related diseases i.e., cohort workers exposed to silica in the milling unit located in Dhand Killi, Mohmand Agency during the follow-up period from 1996 to 2004.

RESULTS AND DISCUSSION

Toxicity and Exposure Level

Toxicity can be defined as the capacity of an agent to produce damage to living organisms. This usually refers to functional (systemic) damage and may be permanent or transient (NOHSC, 1994). The primary determinants of silica toxicity are concentration and duration of dust exposure, particle size distribution, the crystalline isomorphs (alpha-quartz, tridymite, cristobalite, in increasing order of potency), and the presence of a freshly fractured surface. Particles of about 5 μm or less in aerodynamic diameter penetrate to the small airways and alveoli and are then available for phagocytosis by macrophages, resulting in induction of an acute alveolitis and subsequent fibrosis. If the particle is fresh (fractured within 6 hours or less) or has adsorbed materials on the surface, toxicity may be greatly increased (Fubini et al., 1995; Fubini, 1997; Donaldson & Borm, 1998).

The current study indicates that the rock samples of silica (quartz) contain $>92\%$ SiO_2 (Table 1). The XRD data of rock as well as the air samples display the crystalline isomorphs of alpha or low quartz (Table 2 and 3). The XRD diffractogram also shows clear and prominent peaks of low or alpha quartz (Fig.1). The exposure level to respirable particulates including $PM_{10, 7,5,3,2, <2 \mu m}$ ranges from 1-14 mg/m^3 per 1 hour in the indoor environment is multi-times $>$ than the recommended exposure level ($0.05 mg/m^3$).

TABLE 1. CHEMICAL ANALYSIS OF ROCK SAMPLES (QUARTZ)

	Location	
	Dhand (Mine 1), Mohmand Agency	Dhand (Mine 3), Mohmand Agency
SiO_2	91.65	92.00
TiO_2	0.10	0.10
Al_2O_3	0.45	0.45
Fe_2O_3	0.01	0.01
MnO	0.01	0.01
MgO	2.10	2.10
CaO	3.57	3.55
Na_2O	0.52	0.52
K_2O	0.01	0.01
P_2O_5	0.02	0.02
Ig.loss	0.10	0.10
Total	98.54	98.91

TABLE 2. XRD ANALYIS OF QUARTZ ROCK SAMPLES

S. #	Location	D Values				Type of Quartz
1	Mine 1 Dhand Killi	D	3.335	4.24	1.815	Low Quartz
		I	100	20	12	
2	Quartz milling unit 1 Dhand Killi	d	3.335	4.24	1,815	Low Quartz
		I	100	20	12	
3	Quartz milling unit 2 Dhand Killi	d	3.335	4.24	1.815	Low Quartz
		I	100	20	12	

TABLE 3: XRD ANALYSIS OF INDOOR AIRBORN PARTICULATE COLLECTED FROM QUARTZ MILLING UNIT DHAND KILLI, MOHMAND AGENCY

Location	Sample size (μ)	Concentration of sample in mg/m^3 during 1Hour	D Values				Type of Quartz
Quartz milling Unit, Dhund Killi Mohmand Agency	10	7.33333	d	3.335	4.246	1.815	Low Quartz
			I	100	20	12	
	7	14.1666	d	3.335	4.246	1.815	Low Quartz
			I	100	20	12	
	5	4.38045	d	3.335	4.246	1.815	Low Quartz
			I	100	20	12	
	3	1.11904	d	3.335	4.246	1.815	Low Quartz
			I	100	20	12	
	2	0.71428	d	3.335	4.246	1.815	Low Quartz
			I	100	20	12	
	>1	1.47619	d	3.335	4.246	1.815	Low Quartz
			I	100	20	12	

Time weighted Average Recommended Exposure Limit (REL) =0.05 mg/m^3 per 8 hours

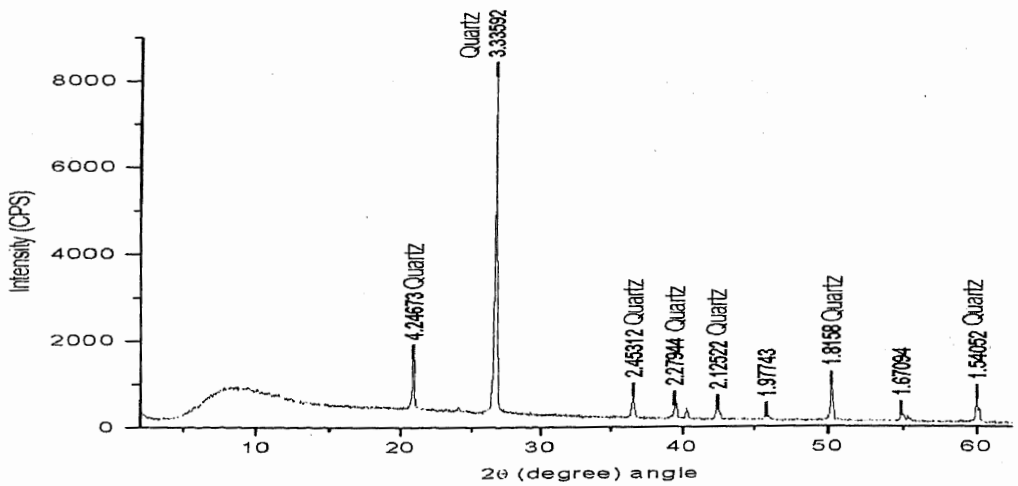

Fig. 1. Alpha quartz peaks in the X-Ray Diffractogram of (PM2μ) indoor sample collected from Quartz milling unit, Dhand Kili, Mohmand Agency.

Evaluation of Health Effects

During this study various lung diseases including silicosis, silicotuberculosis, and pneumoconiosis and lung cancer were observed among the silica miners, millers and their families in Dhand Killi, Mohmand Agency. Almost nine deaths were recorded and verified from the diseases registry recoded in the Lady Reading and Khyber Teaching hospitals Peshawar during the follow-up period from 1996-2004. All of them were silica miners and millers and were highly exposed to respirable silica dust during mining and milling. Apart from that it was also known through the silica workers that some of their family members especially women were also died of unknown lung diseases.

The overall analytical data reveals that the type of silica dust particles released during mining and milling is almost pure and respirable low or alpha quartz. The extent of exposure scenario to respirable quartz dust particles in Dhand Killi is many fold > than the standard limit (0.05 mg/m^3 per 8 hours in Dhand Killi. The exposure response relationship and the health effects are well documented. Based on the analytical results it is concluded that this study can be used as a benchmark for further investigation and guidelines required to control and monitor the silica related environmental health hazards. Although the number of samples are admittedly too small but may be considered as representative case for all other silica (quartz) industries in Pakistan.

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