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Original Article

Risk Assessment of Exposure to Silica Dust in Building Demolition Sites

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ABSTRACT

Background: Building demolition can lead to emission of dust into the environment. Exposure to silica dust may be considered as an important hazard in these sites. The objectives of this research were to determine the amount of workers' exposure to crystalline silica dust and assess the relative risk of silicosis and the excess lifetime risk of mortality from lung cancer in demolition workers.
Methods: Four sites in the Tehran megacity region were selected. Silica dust was collected using the National Institute for Occupational Safety and Health method 7601 and determined spectrophotometrically. The Mannetje et al and Rice et al models were chosen to examine the rate of silicosis-related mortality and the excess lifetime risk of mortality from lung cancer, respectively.
Results: The amount of demolition workers' exposure was in the range of 0.085–0.185 mg/m^3. The range of relative risk of silicosis related mortality was increased from 1 in the workers with the lowest exposure level to 22.64/1,000 in the employees with high exposure level. The range of the excess lifetime risk of mortality from lung cancer was in the range of 32–60/1,000 exposed workers.
Conclusion: Geometric and arithmetic mean of exposure was higher than threshold limit value for silica dust in all demolition sites. The risk of silicosis mortality for many demolition workers was higher than 1/1,000 (unacceptable level of risk). Estimating the lifetime lung cancer mortality showed a higher risk of mortality from lung cancer in building demolition workers.

1. Introduction

Workers in construction industries are exposed to occupational hazards. According to the Iranian Social Security Organization, construction industries have high rates of occupational injuries and health hazards due to unsafe work environment. The high rates of death and disability were recorded in these industries in Iran [1]. Building demolition can lead to emission of dust into the environment. Construction dust contains several compounds such as crystalline silica, significant levels of lead, and other toxic or carcinogenic agents [2,3]. Exposure to silica dust may be considered an important hazard in the demolition sites and construction activities [2,4]. Silica dust exposure can be important in some demolition activities for instance breaking, cutting, crushing, and grinding. Crystalline silica (SiO_2) is the most abundant component in the earth and is used as the fundamental building blocks of structures [5,6]. Also, building demolition workers may be at increased risk for asbestos-related disease [6,7]. The international Agency for Research on Cancer classified some types of crystalline silica such as quartz and cristobalite as Group 1 (known human lung carcinogen) of carcinogens [8,9]. The current and previous threshold limit values for respirable silica dust are 0.025 mg/m^3 and 0.05 mg/m^3, respectively [8]. Rappaport et al [3] reported that numerous of workers have been overexposed to crystalline silica dust in construction sites and the highest exposure was found in painters (1.28 mg/m^3). The Occupational Safety and Health

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Administration (OSHA) has reported that > 2 million of general, maritime, and construction industry workers are exposed to silica dust in their work environment [10]. Occupational exposure to silica dust is thought to cause silicosis in construction workers [11].

Silicosis is the major industrial lung disease and was defined as nodular lesions that may follow with progressive massive fibrosis in lungs [12]. Between 1987 and 1996, 6,300–7,300 new cases of silicosis were described at each year in the USA [11]. Concentrations of respirable silica dust in breathing-zone air of exposed individuals and duration of exposure are the most potent risk factors for developing of silicosis and a clear effect of cigarette smoking on the etiology of silicosis could not be identified in some studies [8]. Also, the results of some epidemiological studies indicate that silica dust is the leading cause of chronic obstructive pulmonary disease and lung cancer in many workers [13,14]. Toxicological risk assessment allows evaluating the public health conditions [15]. In the new global toxicology, risk assessment has become a central issue for estimating the true risk and hazards of toxic agents [8,16]. The risk of death due to silicosis after 45 years of silica dust exposure (0.05 mg/m^3) in a pooled analysis of six cohorts was 6/1,000. OSHA has determined that acceptable level of risk is 1/1,000 workers [17]. The results of Azari et al's [8] investigation in the construction industry showed that geometric mean of exposure to crystalline silica dust was 0.193 mg/m^3 for workers.

Occupational exposure to silica dust has been shown to increase the risk of mortality from lung cancer in workers. Rice et al's [14] model has been developed and introduced to measure the excess lifetime risks of death from lung cancer based on 45 years of silica exposure with a lag of 10 years of 0.05 mg/m^3 silica exposure. Previous research findings have reported the excess lifetime risk of mortality from lung cancer of 19/1,000 workers [8].

However, little attention has been paid to determine the exposure levels of workers to crystalline silica dust and assessment of mortality and lung cancer risk from exposure to silica dust in building demolition sites in Iran. The objectives of this research were to determine the amount of workers' exposure to crystalline silica dust in building demolition sites and assess the relative risk of silicosis mortality and the excess lifetime risk of mortality from lung cancer in building demolition workers.

2. Materials and methods

Occupational exposure to silica dust in the building demolition workers was determined in this cross-sectional study. Four sites in the Tehran megacity region in Iran were selected. Site 1 was located in the south part of Tehran city. This site consisted of four houses. Three houses in this site were located on the west side of the main street and one house was situated at the other end of street. Buildings demolition operations were from June 10, 2010 to June 29, 2010. Site 2, which was located in the east part of Tehran city, consisted of three houses. House demolition operations were carried out from July 18, 2010 to August 3, 2010. Site 3 was situated in the west part of the city. In this studied site, three houses were demolished from August 23, 2010 to September 9, 2010. Site 4 included three houses in different parts of a narrow street in the center of Tehran. The demolition operations were performed from May 21, 2011 to July 20, 2011. The choice of the right method of demolition work depends on many factors such as project condition, the availability of equipment, and the sensitivity of neighborhoods [7]. In all studied sites, demolition was performed using workers daily operation. Demolition operations did not contain any dust control systems such as water spray. From three to five demolition workers were employed in each operation. Worker demographic features were recorded in a specially designed form, which included personal factors such as worker's age and work experience, smoking habits, working time and condition, and the use of personal protective equipment such as respiratory protection devices among demolition workers. All workers completed the informed consent. Full-time workers with no past history of lung disease were included in the study. The workers with no full corporation and those unwilling to continue the study were excluded.

Based on the results obtained from pilot study (95% confidence interval and 7% error), samples were collected from breathing zone air of 60 demolition workers (15 samples from each studied site). The sample size (n) was calculated according to Eq. (1):

$$n = \left(\frac{t_{1-\frac{\alpha}{2}} \times sd}{d}\right)^2 \quad (1)$$

where $t_{1-\frac{\alpha}{2}}$ is the quantile of the Student t distribution, sd is standard deviation, and d is desired precision [18].

Workers who had full shift exposure to respirable silica particles and same work (only demolition workers) were randomly selected from four sites. Top-down demolition operation was performed in each studied site. Trucks were used to remove demolition debris. Approximately 14 roll-off bins were removed from each site at 1–2 weeks.

Personal air sampling was carried out from April 2010 to June 2011. Samples were collected during work hours (08:00–16:00) of work days. Meteorological parameters including air temperature and wind speed were observed in each studied site. Several analytical methods were used for analysis of crystalline silica. Personal breathing zone samples were collected during an 8-hour shift working. The National Institute for Occupational Safety and Health (NIOSH) method 7601 was used to determine silica dust in air samples using visible spectrophotometry at 420 nm (Camspec M501 Single Beam Scanning UV/Visible; Camspec Ltd., Leeds, UK) [19–22]. Weighted-mixed cellulose ester (MCE) filter membranes (25 mm diameter, 0.8 mm pore size; SKC Inc., Eighty Four, PA) were used to collect respirable dust from air. A personal sampling pump (Model LTD; SKC Ltd., Blandford Forum, UK) with a flow rate of 1.7 L/min was used for silica dust collection [18,19]. Calibration curves were obtained by spiking 1 mg, 1.5 mg, 2 mg, 2.5 mg, and 3 mg of quartz on MCE filters then absorbance was measured to prepare the standard curve. Silica dust concentrations were calculated according to Eq. (2):

$$C = \frac{A - B}{m.V} \quad (2)$$

where C is the concentration of crystalline silica, (mg/m^3), A and B are the absorbance of the sample and reagent blank, m is the slope of appropriate calibration curve, and V is the air volume [20].

The Mannetje et al's model [17] is one of the more practical ways of assessing silicosis mortality. This model was chosen to examine the rate of silicosis-related mortality with a lag of 10 years. In the Mannetje et al model, cumulative exposure to silica dust (mg/m^3/y) in range of 0–0.99 to > 28.10 with the relative rate of mortality from silicosis in range of 1.00–63.63 was considered. Forty-five years of exposure was determined for calculating the cumulative lifetime exposure for silica dust. For the purpose of risk assessment of silicosis-related mortality, the years of exposure was multiplied by cumulative exposure to silica dust (mg/m^3/y) [8].

The study of the excess lifetime risk of mortality from lung cancer for workers exposed to silica dust was done based on the Rice et al [14] model and formula presented by Azari et al [8] work for 45 years of silica exposure with a lag of 10 years of 0.05 mg/m^3 silica exposure. Excess risks were estimated for workers exposed for 45 years of working lifetime to respirable crystalline silica dust.