Conference Paper

Evaluation of Control Method Failures for Exposure to Sandblasting Silica Dust in a Steel Construction Company, Indonesia

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Abstract

Silica is one of the materials most commonly used for sandblasting in steel construction. Occupational diseases caused by exposure to silica dust occur in several countries, both developed and developing. In order to prevent the occurrence of such diseases, some developed countries have regulated methods to control exposure to silica dust, but in developing countries like Indonesia, methods of controlling exposure to silica dust are not regulated and upper respiratory infection among sandblasting workers still happens. This study aimed to evaluate the failure of implementing methods of controlling exposure to silica dust during sandblasting in a steel construction company in Indonesia. Aspects that were evaluated included control efforts such as the control equipment, ventilation systems, standard operating procedures (SOPs), and the concentration of silica dust in the workplace. The evaluation was conducted by comparing the expected targets of the control efforts with the concentration of silica dust in the workplace. Evaluation results showed that the control methods are sufficient when viewed from the performance of the equipment used. However, in general, the control measures were not effective because high concentrations of silica dust were found in the workplace because implementation of the SOPs was not optimal, and the disparity or variation in the workers understanding of the application of the SOPs. Therefore, the understanding of the procedures and supervision of sandblasting should be increased.

Keywords: sandblasting, silica dust, control method, evaluation of failure

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1. INTRODUCTION

Utilization of almandine garnet $(Fe_3Al_2)(SiO_4)_3$ containing crystalline silica as a sandblasting agent is common in steel construction in Indonesia, as it is a natural mineral

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containing silica, which is considered safe within industry best practices and is permitted to be utilized in Indonesia as per the Indonesian environmental board. Records shown at least 1.7 million USA workers are potentially exposed to crystalline silica [13]. It is estimated that in India there are 11.5 million workers exposed to silica dust in both the organized and unorganized labor sectors [10]. In Singapore, there are 1,666 Chinese people at risk from working with granite (Chia 1991). In Indonesia, there is insufficient data of workers exposed to silica dust even though the utilization of silica is abundant. The Occupational Safety and Health Administration (OSHA) has developed specific controls to set appropriate engineering controls, personal protective equipment, and respirators as well as work practices to protect employees from silica dust by workers [5]. In India, control of silica exposure is an ongoing process, whilst in Indonesia control of silica exposure has not yet been specifically developed.

Inadequacy of crystalline silica exposure protection can result in silicosis, and it is reported that from 1990–1996, there were 200–300 deaths per year, known to have occurred where silicosis was identified as a contributing cause on the death certificates [19], whilst in Indonesia, there have been numbers of silicosis cases allegedly from exposure to sandblasting for steel construction. Based on data collected from company's primary health care, the number of people complaining of upper respiratory infection from alleged exposure to silica increased from 2014 to 2016 (PT X, 2016).

Because many Indonesian companies use silica products for sandblasting, especially in steel construction, and since there is no standardized control methods as per government regulation [2], and crystalline silica is classified as a human carcinogen [9], the authors wanted to evaluate control methods for silica-quartz fraction exposure from almandine garnet as a sandblasting agent in steel construction companies that already set and comply with industry best practice in Indonesia. It is hoped that in the near future this evaluation will be a reference for the development of safe working methods for silica utilization in order to efficiently and effectively protect workers.

1.1. Research Aim

This study aimed to evaluate the effectiveness of controls to reduce exposure of workers to crystalline silica by comparing the amount of silica exposure to occupational exposure levels (OELs) set by OSHA; Permissible Exposure Limits, American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values, and Indonesian law regulating OELs as well as risk assessments of silica-quartz exposure.

2. METHODS

The subject of this study was the steel fabrication yard of an engineering, construction, procurement, and installation company that supports oil and gas industries and undertakes sandblasting using the above-mentioned sandblasting agents. The study used a cross-sectional study method to evaluate the controls, focused on process-fugitive sources over certain time intervals, and initiated a description and assessment of a sandblasting design control philosophy, dust suppression and ventilation systems, and standard operating procedures for carrying out sandblasting [11]. Evaluation of the controls was determined by the amount of silica (size selective sampling was used to measure the respirable phase) and calculation of the silica-quartz dose exposure to workers as a fraction of the silica [16].

3. RESULTS

3.1. Sandblasting Design Control Philosophy

Sandblasting produces large amounts of silica dust due to the utilization of pressurized air to blast the sandblasting agent via a blasting pot. To prevent dust-pollution in the workplace, sandblasting is done in a fully enclosed area fabricated from metal with an access way, the so-called sandblasting room [5]. There were two identical sandblasting rooms, fully designed and designated areas, to carry out sandblasting. No massive sandblasting activity was allowed or permitted unless it was in this designated area, and only a limited number of workers were permitted to take part in this activity. Through this safety philosophy, exposure of non-related workers to silica and quartz-silica will be reduced, so the risk of exposure will be low [5].

3.2. Dust Suppression and Ventilation Systems

Local exhaust ventilation was utilized to support the sandblasting room operation consisting of hoods, ducting, fans, and air cleaners [12]. Flanged multiple-slot opening hoods (200 mm wide by 500 mm high) directed at the sandblasting were located around 1,200 mm above ground, and airflow was suctioned through fixed galvanized ducting connected to the hood particulate filters, commonly called a baghouse, to collect the silica, which is regularly cleaned and maintained. The suction system that draws off the contaminated air used radial blade fans with air flow rates of 25,000

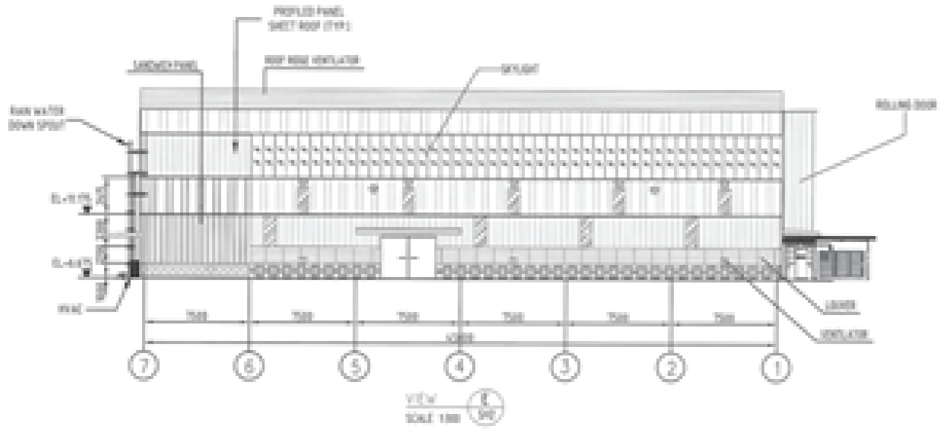

Figure 1: Sandblasting room design.

m^3/h, with the fans total head ca. 240 mm. Compressed air was required, 0.4 m^3/min, and it was assumed that the make-up of the air was more than 10% of the exhaust rate and there was no pressure loss in the ducts. Based on the calculation of airflow principles provided by design engineering compared to silica exposure, which has a heavier mass than air, it was found that the exhaust system capacity was adequate [18].

3.3. Sandblasting Standard Operation Procedure

Protection of workers from sandblasting focusing on occupational health and safety was clearly mentioned on the sandblasting safe work practice procedure. The procedure included a safety measure standard, administrative requirements such as a pre-job start meeting, a toolbox talk, and the requirement that employees must attend health and safety promotions specific to sandblasting prior to commencing the activity via a classroom training session [5]. In order to implement occupational health in this activity, it was mentioned that sandblasting workers would be equipped with respiratory protection equipment (RPE) with specific characteristic. The RPE supplied respirator air sourced from an air compressor through a flexible hose containing a CPF air filter with a High Efficiency Particulate (HEPA)100 class filter [3]. The volume of compressed air for breathing was 20 cfm at 90–100 psi when using a Cool Air Tube. The OSHA assigned protection factor for this respiratory protection system is 1000 Based on the OEL of almandine garnet, this helmet could hold 4000 mg/m3 silica dust exposure.

Disparity was observed when sandblasting commenced and the sampling was in progress. Safe working required that when the sandblasting room was in operation

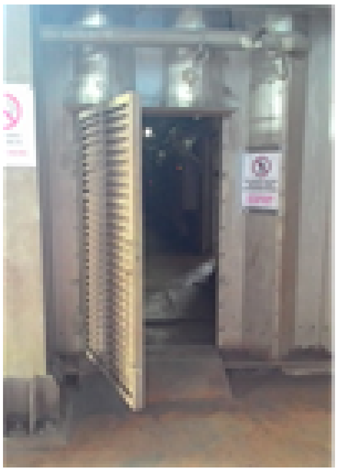

Figure 2: Disparity in standard operating procedure – access door open when sandblasting was taking place and lack of a self-closing non-gasketed door.

all opening should be closed to enable the ventilation system to work effectively, but this was not done and silica dust was released into the surrounding environment [5]. Another disparity was also observed in the construction of the sandblasting-room door, which should have been a self-closing gasketed door [5].

3.4. Determination of Control Effectiveness

3.4.1. Measurement of Respirable Size Silica Exposure

Exposure data sampling collection was done by a third-party government owned laboratory accredited by the Indonesian Committee of Accreditation ("Komite Akreditasi Nasional" – KAN) complying with ISO 17025 for laboratory management systems. Sampling was done around the second quarter of 2015 between June 10and June 11, 2015 during dayshift sandblasting using sampling method NIOSH 7500 for collecting silica dust in ambient air [4]. There were eight sampling points located around the sandblasting room. The measurements showed that silica exposures were greatly above the OEL at all sampling points, and it is suggested that this happened because of the disparities described in the previous assessment section.

3.5. Calculation of Silica-Quartz Dose Exposure to Workers

Instead of measuring silica dust to evaluate the controls, evaluation to measure the quartz fraction of the silica exposure, when silica is being utilized as a sandblasting

Table 1: Silica sampling measurements compared to OEL.

Sampling point identification number	Sampling area	Measurement result (mg/m^3)	OSHA PEL (mg/m^3) (OSHA 2011)	ACGIH TLV (mg/m^3) (ACGIH 2016)	OEL by Permenaker no 13 year 2011 (mg/m^3) (Indonesian Ministry of Manpower 2011)
2	Blasting Room B, Blasting Structure	127.54	0.025	0.025	10
3	Blasting Room B Aisle Area, Blasting Structure	124.82	0.025	0.025	10
5	Blasting Room B, Blasting Structure	127.54	0.025	0.025	10
6	Blasting Room B Aisle Area, Blasting Structure	124.82	0.025	0.025	10
9	Blasting Room A, Blasting Pipe	123.40	0.025	0.025	10
10	Blasting Room A Aisle Area, Blasting Pipe	116.15	0.025	0.025	10
11	Behind Blasting Room A (Silo Area), Blasting Pipe,	110.75	0.025	0.025	10
12	In Front of Blasting Room A, Cleaning, and Preparation of Blasting Activity	108.21	0.025	0.025	10

agent, by calculating a lifetime average daily dose (LADD), a risk for carcinogen (RfD), and a lifetime risk for carcinogens were calculated using some equations [7].

$$ADD = \frac{C_{sampling\ point\ 2} \cdot c \cdot IR \cdot RF \cdot EL \cdot AF \cdot ED \cdot 10^{-6}}{BW \cdot TL}$$

$$RfD = \frac{MDD}{ADI}$$

$$Risk = LADD \cdot SF$$

Exposure evaluation was assumed by using several presumptions and assumptions based on field observations and literature references as applicable. It was assumed that no respiratory protection equipment was used, but dermal protection was fully in place to protect the whole body, so it was assumed that there was no dermal exposure when the sandblasting took place. It was presumed that over eight hours of work time, workers were exposed to the respirable form of silica quartz for around seven hours, for around 300 days per year. Workers were typically adult males aged 25-years-old with an average body weight of 70 kg with an assumed typical lifetime of around 30 years. Based on the referenced literature, sandblasting is categorized as a heavy activity and a typical adult male inhalation rate for heavy activity is 4.8 m^3/hour [14].

The respirable fraction of the silica was assumed to be 100% using an aerodynamic diameter of around 3μm and the concentration of quartz in the almandine garnet was set at 0.5% w/w or 5,000 mg/kg.

Because the subject of the current research is the toxicity of quartz, the human dose response was interpolated from the dose response effect of silica quartz to animals [7] using a human equivalent dose equation. The human dose of an agent is expected to induce the same severity of the toxic effect that an animal dose induced. The value of the Human Equivalent Dose (HED) is the extrapolation to humans of silica exposure concentration to rats, which in the laboratory experiment was five hours per day; four days a week for one year to determine the retardation clearance rate or time from the respiratory region of the lungs. Thus, a lower clearance rate or time will cause deposits of silica in the respiratory region that lead to persistent inflammation neutrophils, which creates oxidants than can cause tumors in the respiratory region if the exposure is latent; decrease lung volume; decrease respiratory system compliance; decrease the N2 slope; decrease diffusion capacity for carbon monoxide; and decrease flow expiratory force [14].

$$HED = \text{rat exposure concentration to silica} \cdot \left(\frac{\text{human body weight}}{\text{rat body weight}}\right)^{\frac{1}{3}}$$

$$HED = 21.1\frac{\text{mg}}{\text{m3}} \cdot \left(\frac{70}{0.25}\right)^{\frac{1}{3}}$$

$$HED = 21.1\frac{\text{mg}}{\text{m3}} \cdot 6.5421$$

$$HED = 138.0389\ \text{mg/m3}$$

This means that if silica exposure to a worker via inhalation exceeds 138.034 mg/m^3 for such time, adverse health effects as mentioned may occur. Instead of calculating the HED, the acceptable daily intake was also calculated to determine the safe exposure level per day of quartz silica in the workplace.

The sampling results from the eight sampling points showed variation in the data based on the characteristics of the location and exposure criteria. However, the focus of the current research was quartz silica found as 0.5% w/w in almandine garnet. Thus, the level of quartz exposure was calculated from the lifetime average daily dose using the presumptions mentioned previously.

Calculations of lifetime average daily doses from the several sampling points were directly proportional with the measured silica from the sandblasting. Quartz LADD calculations showed that the lifetime average daily dose from sandblasting, based on the presumptions above, were still below the HED until it became symptomps on human body. Furthermore, the risks for carcinogens were mostly insignificant for those amounts of exposure as the Lifetime Average Daily Dose (LADD) were mostly below the HED. Whilst the risk for lifetime cancer from quartz exposure by this amount of almandine garnet usage were insignificant, the severity factor (SF) of quartz inhalation was determined as 10–6 (risk is insignificant) [7].

Table 2: Calculated toxicity risk assessment of quartz silica from sandblasting.

Sampling point identification number	Sampling area	LADD from Inhalation of Quartz in Air (mg/kg body weight/day)	RfD Risk for Carcinogen	Risk for lifetime cancer
2	Sandblasting Room B, Blasting Structure	0.3	0.075	$0.3 \,.\, 10^{-6}$
3	Sandblasting Room B Aisle Area, Blasting Structure	0.299	0.0748	$2.99 \,.\, 10^{-7}$
5	Sandblasting Room B, Blasting Structure	0.3	0.075	$0.3 \,.\, 10^{-6}$
6	Sandblasting Room B Aisle Area, Blasting Structure	0.299	0.0748	$2.99 \,.\, 10^{-7}$
9	Sandblasting Room A, Blasting Pipe	0.296	0.074	$2.96 \,.\, 10^{-7}$
10	Sandblasting Room A Aisle Area, Blasting Pipe	0.278	0.0695	$2.78 \,.\, 10^{-7}$
11	Behind Sandblasting Room A (Silo Area), Blasting Pipe,	0.2658	0.06645	$2.658 \,.\, 10^{-7}$
12	In Front of Sandblasting Room A, Cleaning, and Preparation of Blasting Activity	0.259	0.06475	$0.259 \,.\, 10^{-6}$

4. CONCLUSIONS

The authors concluded that the control methods for using almandine garnet $(Fe_3Al_2)(SiO_4)_3$ for sandblasting in steel construction were adequate but ineffective because of disparities observed in the standard operating procedure that resulted in a high level of exposure. It was concluded that sandblasting should be done in a fully closed system to prevent high exposures outside the sandblasting room.

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