RESEARCH ARTICLE

Preventive Strategies for Reduction of Occupational Exposure of Free Crystalline Silica Dust in Steel Foundry and Stone Crusher Unit

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Abstract

Mineral extraction operations are characterized by large quantities of dust emission in the environment. Persons who are working in such environments are potentially exposed to the harmful effects of respirable mineral dust, such as impaired lung function. This study investigated the prevalence and correlated the lung function impairment and dust concentrations with different preventive measures followed in the steel foundry as well as stone crusher workers in West Bengal, an eastern part of India.

This cross-sectional study was conducted on steel foundry workers and workers employed in stone crushing units. Both types of workers are exposed to free crystalline silica dust in their workplaces. To assess the effectiveness of control measures of dust, the lung function impairment was correlated with types of Personal Protective Equipment (PPE) used by them. The results were analyzed using statistical tools, Pearson's correlation coefficient, and Chi-square test to evaluate the significance level.

The PPEs used by them were not proper, so it did not prevent lung function impairment for the reduction of airborne dust concentration levels at the stated workplaces, a sprinkling of water was applied. Before and after the sprinkling of water, dust concentration was measured using the NIOSH method-7601 and 7602 (CDC, 2005). The concentration of dust level before and after the application of water sprinkling was found to be statistically significant by using a t-test ($\alpha<0.05$). Therefore, the periodical water sprinkling method may be applied as a preventive measure for the exposure of dust at work and environment. Use of proper PPE and other recommendations should be implemented.

Keywords: Crystalline Silica Dust, Steel Foundry, Stone Crusher Unit.

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Introduction

Industries use a whole series of rocks, collectively known as a stone. Natural stone may be of hard and soft varieties. The present study is mainly concerned with sandstone that is consist of quartz grains and used in different industries and sometimes for making abrasive tools. The sandstone is rich in silica and occurs almost everywhere in the earth's crust. Its structure is crystalline.[1] Stones are usually evacuated in open crust quarrying by drilling, cutting, and followed by loading. Big bold rocks are collected and transported to different workplaces and subjected to cut into different shapes and sizes, or through manually operating stone crushing or mechanized stone crushing processes.[2] Some of the workplaces like steel industries, fine sands (mess size) are collected from the different sources to make the desired size of the core container by the process of blasting, core making, fettling, casting fabrication, etc. During these processes, workers are exposed to different types of hazards, mainly airborne dust, apart from other physical hazards like heat, cold, noise, and vibration.[3] The airborne dust in the workplaces not only irritates the upper airways bronchi but also causes pneumoconiosis and other respiratory impairments.[4] Therefore, a preventive measure should be necessary for the reduction of dust levels and concentration of airborne toxic substances in the work environment.[5] The impact of airborne dust likely caused functional disorders of the respiratory system.[6] Although different recommendations are made by ILO, in practice, it was hardly followed in unorganized sectors.[7]

This study investigated the prevalence and correlated the lung function impairment and dust concentrations with preventive measures followed in the steel foundry as well as stone crusher workers in West Bengal, an eastern part of India.

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Materials and Methods

Sample Collection

The sampling was done in the different locations of a steel foundry and six different stone crusher units. Dust samples (N=42) were collected from seven locations of steel foundry and dust samples (N=36) were collected from four locations of six different stone crusher units through the personal sampling methods.[8]

Pulmonary function data were also collected from 899 workers working in a steel foundry and 152 workers engaged in stone crusher units with the help of the portable spirometer SP-10 (shriller make). The methodology of the pulmonary function test is a detailed explanation of the lung function test including the measuring procedure, a minimum of three lung function measurements were recorded. Spirometric maneuvers were conducted according to the recommendations of the American Thoracic Society (ATS)/ European Respiratory Society (ERS) Task Force on lung function testing and compared to the reference of the European Community for Coal and Steel (ECCS).[9] Following the manufacturer's guidelines, the systems were calibrated daily. After three satisfying recordings of static lung volumes, minimal three forced flow volume maneuvers were performed, starting from residual volume (RV) with a deep and forced inspiration, followed by a forced and maximal expiration. Only those measurements were accepted where the expiratory time (T_E) exceeded four seconds, the variation of end-expiratory flow was below 25 mL/s and no cough disturbed the expiratory phase.[10] All measured lung volumes obtained were expressed in terms of body temperature pressure saturated with water vapor (BTPS). The respiratory data were collected by competent personnel of the health care unit.[11]

The methods for controlling the dust containing crystalline respirable free silica focusing on two aspects as given bellow:

a. Sprinkling of water in the work environment as well as to the materials used.[12]

b. Use of different PPEs to prevent the air-born inhalation of dust. Unfortunately, in the selected work units, the workers are provided with very low-cost, substandard protective equipment. In the unorganized sector, the workers generally used only a piece of cloth mainly gamcha (local cotton towel) for respiratory protection.[13]

The Sprinkling of Water

The dust concentration level was monitored before and after the application of water sprinkling in different locations of steel foundry and stone crusher units.

Uses of PPEs

It was already pointed out that types of personal protective equipment (PPE) used by the workers are not proper.

The pulmonary function test was performed during work in different locations on the workers are engaged in various tasks with and without PPEs. Impairment of functional status of the lung was assessed by using different statistical tools e.g. chi-square test by SPSS version-24 software. Similarly, a t-test was employed to find out the significant difference of dust concentration before and after the sprinkling of water in the above-stated workplaces.

Results and Discussion

1. Effects of Sprinkling of Water

Figure 1 represents the "Total dust" concentration in different locations of stone crushing units; it appears from figure 1, the concentration of "Total dust" before a sprinkling of water in "front of crusher operator", "near dispatched section", "under crusher (right side)", "under crusher (left side)" were found to be 11.98 mg/m^3, 7.89 mg/m^3,11.51 mg/m^3, 10.70 mg/m^3, respectively and similarly the dust concentration levels of the same four locations were 8.33mg/m^3, 5.75mg/m^3, 8.77 mg/m^3, 7.25 mg/m^3, respectively, after the sprinkling of water. It also appears from the figure-1 that there exists a difference in "Total dust" concentration in four locations of six different stone crusher units. These differences are found to be statistically significant as revealed by the t-test where the $\alpha < 0.05$.

Similarly, an attempt has also been made to monitor the dust concentration level in different locations of the steel foundry. The dust concentration levels in six different locations have been summarized in figure-2. In one location of the steel foundry, i.e. the administrative section, the same method could not be employed due to some administrative reasons. Moreover admin section the dust concentration was very much low. The dust concentration level in different locations were 17.52 mg/m^3, 16.13 mg/m^3, 10.38 mg/m^3, 11.07mg/m^3, 12.78 mg/m^3, 12.52 mg/m^3 before water sprinkling . And after water sprinkling the concentration levels came down to 11.91 mg/m^3, 10.40 mg/m^3, 7.26 mg/m^3,

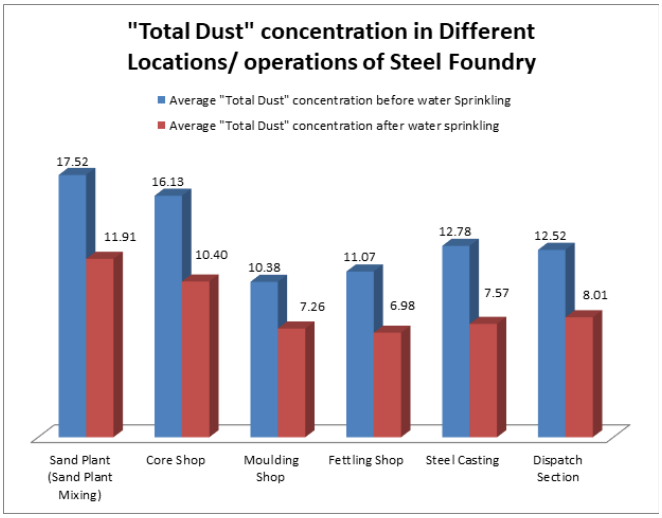

Figure 1: Distribution of average "Total Dust" concentration (mg/m^3) in different location of Steel foundry before and after the application of water sprinkling.

Table 1: Types of PPEs used and lung functions impairment.

Lung functions impairment for steel foundry workers.			
	LUNG FUNCTIONs IMPAIRMENT		
PPE	Impairment	Normal	P-Value
	n (%)	n (%)	
Hard hat	Total= 270	Total=629	0.63
Yes	257 (95.19)	589 (93.64)	
No	13 (4.81)	40 6.36)	
Safety goggles	Total= 270	Total=629	1.01
Yes	221 (81.85)	554(88.08)	
No	49 (18.15)	75 (11.92)	
Respirator	Total= 270	Total=629	0.84
Yes	204(75.56)	515 (81.88)	
No	66 (24.44)	114 (18.12)	
Work suit	Total= 270	Total=629	1.10
Yes	232 (85.93)	487 (77.42)	
No	38 (14.07)	142 (22.58)	
Wearing PPE in the summer	Total= 270	Total=629	0.50
Yes	224 (82.96)	478(75.99)	
No	46 (17.04)	151(24.01)	
Frequency of using PPE	Total= 270	Total=629	0.42
Once	20 (7.41)	40(6.36)	
Sometimes	80(29.63)	245 (38.91)	
All the time	170 (62.96)	344(54.69)	

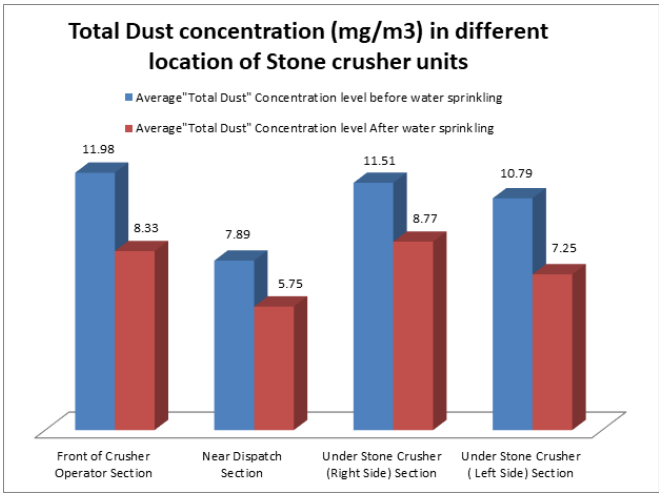

Figure 2: Distribution of average "Total Dust" concentration (mg/m^3) in different locations of Stone crusher units before and after the application of water sprinkling.

6.98mg/m^3, 7.52 mg/m^3, 8.01 mg/m^3, respectively. These differences in the value of dust concentration in six different locations of the steel foundry were statistically significant as revealed by t-test where $\alpha<0.05$. The sprinkling of water for suppression of dust is one of the wet work methods is also advocated by many researchers as well as by ILO (IARC, 191497).

Table 2: PPEs associated with lung functions impairment

Lung functions impairment for stone crusher workers			
	LUNG FUNCTIONS IMPAIRMENT		
PPE	Impairment	Normal	P-Value
	n (%)	n (%	
Hard hat	Total=33	Total=119	1.00
Yes	33 (100)	117(98.31)	
No	0 (0)	2 (1.7)	
Safety goggles	Total=33	Total=119	0.52
Yes	28 (22.9)	108 (90.76)	
No	5 (4)	11 (9.24)	
Respirator (cotton cloth)	Total=33	Total=119	0.53
Yes	28 (85.0)	115 (96.64)	
No	5 (15.0)	4 (3.36)	
Work suit	Total=33	Total=119	1.00
Yes	32 (97.0)	87 (73.11)	
No	1 (3.0)	32 (26.89)	
Wearing PPE in the summer	Total=33	Total=119	
Yes	24 (72.7)	78(65.55)	0.57
No	9 (27.3)	29 (34.45)	
Frequency of using PPE	Total=33	Total=119	
Once	0 (0)	5 (4.2)	
Sometimes	12 (36.4)	45 (37.82)	0.77
All the time	21 (63.6)	69 (57.98)	

2. Types of PPE used and Lung Function Impairment

Table 1 and 2, showed that the percentage of lung function impairment of the study population with or without different PPEs used is not statistically significant in all the cases for stone crusher units and steel foundry workers as P values ranged 0.42 to 1.10.

The PPEs associated with the lung functions impairment in the workers engaged in steel foundry have been summarized in table 1. It can be seen from the table that even after using the respirator the number of cases of impairment was found to be 270 in number against 629 normal cases. However, they are statistically significant as P=0.84. like that other types of PPEs like safety goggles, work suite, working PPEs in summer, hard hat, and frequency of using PPEs have got no significant effect in reducing the impairment of lung function as P values in all these cases were found to be greater than P>0.05.

Similarly, results were also obtained in the case of stone crusher workers different types of PPEs they used, did not have any impact in reducing the impairment level as P-value in all the cases were found to be greater than 0.05 detailed in table 2.

It is patenting to mention here that the stone crusher workers were used cotton cloth instead of proper PPE this may be a lack of knowledge and attitude on the part of the management and workers, so these are not effective enough to reduce the impairment.

The findings of the present study are inconsistent with the study of the other.[15-17] It is also reported that severe lung function impairment could be prevented by the elimination of the habit of smoking[17, 18] The present study also pointed out that smoking has an additive effect for increasing lung function impairment.

The awareness about the hazards, use of appropriate PPEs are very much lacking. In the unorganized sectors, employers hardly take any steps to reduce workplace hazards.

Conclusion and Recommendations

However, some of the recommendations can be made in reducing the dust control as well as reduction of impairment of lung disorder following guidelines would be useful:

1. **Use of Substitutes:** The best way to eliminate exposure is to use materials that don't contain hazardous chemicals. This is an "engineering" approach to hazard control with an engineering approach, one can eliminate hazards by selecting tools and equipments and by designing work processes that are hazards free.
2. **Use of dust contaminant systems:** Other ways to eliminate exposure include installing dust collection systems on machines that generate dust or using enclosed cabinets with gloved armholes to do hazardous tasks.
3. **Work wet:** Use wet drilling or sawing to control dust. Remove dust and debris with a wet vacuum or hose it down, rather than blowing it around with compressed air or dry- sweeping it.
4. **Dust suppression:** Dust suppression can be achieved by the use of water by wet drilling and grinding or in sprays for rock crushers. Enclosures, automation of processes, good housekeeping, and other engineering controls should be enforced where appropriate.[19]
5. **Ventilation:** Use a local-exhaust ventilation system to keep work areas dust-free.
6. **Use of Personal protective equipment when necessary:** Personal protective equipment can protect workers from hazards, but it does not eliminate hazards. If the equipment fails or it's not appropriate for a particular task, a worker can still be exposed.
7. **Administrative control:** It may be necessary to rotate workers between jobs to avoid prolonged exposure in activities and segregation of workers to minimize the number of workers exposed to silica dust.
8. **Environmental monitoring:** Regular measurement of environmental dust levels provides a basis for assessment of control strategy and so that improvement can be made earlier.
9. **Occupational health education:** Workers should be thought about the hazards of silica as well as the proper ways to wear specific protective equipments.[9]
10. **Smoking:** The workers should be advised to quit smoking. Smoking and silica dust exposure is a deadly combination.[20]
11. **Supervision:** It is the responsibility of the management to make sure regular maintenance of the ventilation systems, safe working practice as well as wearing a suitable respirator by workers in hazardous work environment.[21]
12. **Medical Surveillance:** Workers should be ~~a~~ under a comprehensive medical surveillance system in the form of pre-employment medical examinations and annual periodic medical examinations (CDC, 1995). Baseline and periodic chest radiograph and lung function tests should be done for early detection of adverse effects of silica. Compensation is generally a reflection of failure of prevention. However, some short of compensation is better than nothing if workers are already suffered from the disease.[22]
13. Some of the recommendations have been adopted from International Labour Organisation (ILO) convention 1999. These policy decisions, if properly implemented, will ameliorate the problems of silicosis.[5]

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