RESPIRATORY HEALTH STUDY OF BRICK INDUSTRY WORKERS, SURVEY AND ENVIRONMENTAL ASSESSMENT

By

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Abstract

Introduction: Brick production is a widely distributed industry ensure the main material demanded for the up growing urbanization. Type of used fuel beside silica exposure represents two occupational risk fangs at and around work site. **Aim of Work:** To study the respiratory affection and pulmonary function tests (PFTs) among brick industry workers and to assess silica and dust levels in different exposure areas

Materials and Methods: The cross-sectional study included 350 workers at brick factories in Arab Abo Saeed region, Egypt. Full medical and occupational histories were taken, and clinical examination was done with special emphasis to the respiratory system. Pulmonary function tests were held which included (FV_C, FEV_1, FEV_1/FV_C, MEF_{25}, MEF_{50}, MEF_{75} and PEF). Dust samples were collected from the work sites at the breathing zone using a personal sampling pump and a size-selective cyclone; environmental assessment of samples was done using X ray powder diffraction method. Results: The most prevalent manifestation among workers was shortness of breath (28.6%). Testing pulmonary functions of workers revealed restrictive pattern (guided with FVC<80%) in 44.7% of workers while obstructive pattern was found only in 14.9% of workers. Both respirable silica and respirable dust exposure levels exceeded the current national and international permissible limits. **Conclusion and Recommendations:** Working in brick industry represent a threat to the workers respiratory health. Even after shifting to natural gas as cleaner fuel, high levels of respirable silica and dust in the workplace which may be responsible for the negative impact on pulmonary functions. Special attention and more strict control measures should be followed not only to damp silica and dust particles exposure but also to .revise permissible limits

Key words: Brick industry, Silica dust, Environmental assessment, Pulmonary function .tests and Respiratory affection

Introduction

Brick is the cornerstone of both traditional and highly growing modernized construction sites. Being such fundamental highly demanded industry, it relies on ten thousand workers and represents the main income source to their families. This sector of huge highly productive manpower works unfortunately in a threatening workplace (Anwar et al., 2018).

Multi physical exposures could harm workers health. Sun and heat exchanged by radiation and convection outside and inside kilns causes heat stress disorders. Exposure to ionized and nonionized radiation (USDOL 2002), ultraviolet rays and noise are other physical hazards at the workplace (Thygerson et al., 2016). Work-related musculoskeletal disorders (WMSDs) are frequent in relation to heavy workload transportation, postural issues and repetitive movements (Sanjel, 2018).

Other than physical hazards, chemical toxins harm body on contacting it. In brick industry toxin emission could be due to fuel combustion or silica particles. Carbon, Sulfur and Nitrogen oxides beside particulate matter (PM) smoke represent secondary emission from fuel consumption. These levels widely vary and thus variable air quality results according to the fuel used (Shaikh et al., 2012).

In 2010 an environmental project was held in Egypt aiming at replacing heavy fuel oil (HFO) in Arab-Abosaeed brick factories by natural gas (NG). Environmental assessment supported the great value of this fuel conversion on improving air quality at and around the working area. Stack emission of PM, sulfur dioxide (SO2), and Nitrogen dioxides (NO2) reaches 67.8 mg/m^3, 82.5 mg/m^3 and 70.9 mg/m^3 with NG instead of 1696.5, 96.434 and 139 mg/m^3 with heavy fuel oil (HFO) respectively. $PM_{10\%}$ of PM decreased from 96 to 43.55% (Higazy et al., 2019). Concentration pollutant air gases greatly eliminated on using cleaner source of fuel and new stack technologies (Khan et al., 2019).

Dense inhalation of dust with crystalline silica as a main component of clay is a furious chemical theat. Lungs as an entrance gate accumulate and enclose large quantities of such chemical pollutant (Beard et al., 2022). Being small enough to enter the respiratory bronchioles and alveolar regions, it accumulates in gas exchange layers causing irreversible scarring thus destroying lung capacity. Silicosis as a resultant occupational lung disease causes irreversible, non-curable lung injury (USDOL 2002). Pulmonary tuberculosis has strong epidemiological evidence to be associated with occupational exposure to crystalline silica exposure (Ehrlich, 2021). There is also association between silica exposure and other diseases like renal diseases (glomerulonephritis) and autoimmune diseases (rheumatoid arthritis) (Mohamed, 2018).

Monitoring of occupational exposure to crystalline silica and dust is obligated by government legislation. It is a multi-phase process. Environmental measurements at workplace represents on field step. It is followed with quantitative analyses of samples, then comparison of results with the permissible limits (ACGIH 2010a). American Conference of Governmental Industrial Hygienists (ACGIH) set 3mg/m^3 for total dust (ACGIH 2010b). Both ACGIH and occupational safety and health administration (OSHA) updated threshold limits of 8-hr working daytime weighted average (TWA) of crystalline silica to 0.025mg/m^3 (OSHA, 2016). Egyptian law took the basis of ACGIH 2002 in Egyptian labor law No. 211/2003 accepting 1mg/m^{3}TWA for respirable silica and now working to update it (Aziz et al. 2010).

Aim of Work

To study the respiratory affection and pulmonary function tests (PFT) among brick industry workers and to assess silica and dust levels in different exposure areas.

Materials and Methods

Study design: It is a cross-sectional study.

Place and duration of the study: The study was carried out in brick production factories in Arab-Abosaeed, Helwan governorate, Egypt during the period from February 2018 to March 2019. The plant has been in operation since 1970 but was shifted to work with natural gas instead of heavy mazot fuel and garbage since 2010.

Four main steps controls brick production. First is preparing of clay from soil (purifying from impurities, mixing with water and additives and tempering). Second step is molding of clay by a traditional machine. Next is drying of casts naturally in sun. Finally firing of dried brick in special kilns (Thygerson et al., 2016).

Study sample: The study included

350 workers who worked for a minimum of 8hours/day, 5days per week and involved in work more than 1 year ago. All workers in the production unit were men. They worked at open areas and no personal protective equipment (PPE) was used. **Inclusion criteria**: workers who are working as clay carriers, brick molders and kiln loading and directly exposed to brick dust. **Exclusion criteria**: workers indulged in another extra work with dust exposure (coal workers, cement workers), uncooperative to Pulmonary Function Tests (PFTs) or worked in brick industries for less than 1 year.

Study method

- **Pre-designed Questionnaire:** Full history was obtained according to a pre-designed questionnaire, including personal, occupational, present, past and family histories with special emphasis to respiratory manifestations.

- **Clinical examination:** Full clinical examination was conducted to the studied group with more focus on respiratory assessment. The weight and height were taken from the study groups using a medical weighing scale with a mechanical height rod and body mass index (BMI) was calculated.

- **Pulmonary function tests:** Forced expiratory volume in first second (FEV_1), Forced vital capacity (FVC), and the ratio of these parameters (FEV_1/FVC ratio), Peak expiratory flow rate (PEF), Maximal expiratory flow rates in 25%, 50% and 75% of FVC ($MEF_{25\%,}$ $MEF_{50\%}$ and $MEF_{75\%}$) and Maximum voluntary ventilation (MVV) were measured for the studied group using a portable spirometry (Ganshorn Medizin Electronic). For each parameter, the highest value of three reported trials was recorded. Parameters were expressed as percentages of the predicted values to the reference controls based on age, gender, weight, and height parameters. Test was held in an administrative office at tework field. Before test performance, all steps and procedure were well demonstrated to each subject. During the tests, the participants were comfortably seated in an upright position, inserting sole use mouthpiece and nose clip. The participants were encouraged to perform deep, rapid inspiration followed by deep, rapid expiration. Once the lungs' air had been expelled, subjects breathe as quickly as possible (with the transducer placed in the mouth) until the lungs were full. Cutoff levels of ATS/ERS were the base of interpretation with normal pattern interpretation of the data was recorded, included normal pattern (normal FVC, normal FEV_1/FVC ratio), an obstructive pattern (reduced FEV_1/FVC ratio, below 70) and a restrictive pattern (reduced FVC below 80%) (Miller 2005).

- **Environmental assessment: for both respirable dust and silica**

a. Work place measurement of respirable dust fraction and silica:

During 12 visits, seventy-six air samples were taken at different sectors in the plant. The respirable dust fraction was measured using the Respirable Plastic Cyclone (Higgins-Dewell) sampler with plastic cassettes (Casella) at flow rate of 2.2 l/min with GIL Air gas pump. The flow rate of the sampling train was checked according to ISO EN 13137. The cyclones were fixed on workers clothes, attached to belt and collar at breathing zone. When the flow rate before and after sampling deviated more than ±5%, sample was discarded.

In the sampler cassette a 25mm–5μm pore GLA-5000 PVC Membrane Filters (SKC part number 225-5-25) was used as sampling substrate. The filters were then sent to.

b. Bulk samples mineralogy and environmental samples measurements for respirable dust and silica were done using X-ray powder diffraction,

The analysis consists of the bulk mineralogical analysis of the sample by X-ray diffraction according to ISO16258-1. The sample was first dried in an oven at 60°C. After drying, a part of the sample was milled in wet milling device. The sample was then managed to avoid any preferred orientation of the minerals, then loaded into an X-ray diffraction (XRD) sample holder and measured by X-ray diffraction using CuKalfa radiation. The mineralogical composition of a finely milled sample can be determined quantitatively, X-rays which interact with the different minerals in the sample. Based on the crystal structure and atomic occupancies of each mineral, the interaction will produce constructive or destructive interference of the reflected X-rays depending on the angular incidence of the X-rays, Braggs' law. The subsequent quantification was performed by an in-house method based on the Rietveld method (ISO16258-1; Kumar and Rajkumar 2014).

All samples were analysed in the Belgian centre for Occupational Hygiene.

Consent

Approval of the administrative authority and consent from the studied population were obtained after information of study plan and procedures.

Ethical Approval

The study protocol was approved by the Ethical Committee of the Department of Occupational and Environmental Medicine, Faculty of Medicine, Kasr AlAiny, Cairo University, Egypt.

Data Management

Data were coded and entered using the statistical package for the Social Sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA). Data was summarized using mean, standard deviation, median, minimum, and maximum in quantitative data and using frequency (count) and relative frequency (percentage) for categorical data. Comparisons between quantitative variables were done using the non-parametric Mann-Whitney test (Chan 2003a). For comparing categorical data, Chi square (c2) test was performed. Exact test was used instead when the expected frequency is less than 5 (Chan 2003b). Correlations between quantitative variables were done using Spearman correlation coefficient (Chan 2003c). P-values less than 0.05 were considered as statistically significant.

Results

The present study was conducted on 350 subjects working in brick industries and directly exposed to silica brick at Arab-Abosaeed, Ain-Helwan, Cairo, Egypt.

The age of the studied group ranges from 14 to 87 with a mean of 34.06 years. Duration of exposure varied from 1 to 60 years. Most of the participants' residents were in rural areas (88.1%). About 64% are smoking, mainly cigarette smoking (76.5%), with mean of smoking index (187.86%). Drugs were abused by 26.5% of he studied group.

Table (1): Frequency of general and respiratory manifestations among the studied workers.

Respiratory manifestations		**No**	**%**
Chest pain	Yes	22	6.3%
Shortness of breath	Yes	100	28.6%
Cyanosis	Yes	0	0.0%
Clubbing	Yes	9	2.6%
Dry cough	Yes	18	5.1%
Hemoptysis	Yes	6	1.7%
Expectoration	Yes	68	19.4%

Table 1 showed that shortness of breath was the commonest respiratory manifestation among brick workers (28.6%), followed by expectoration (19.4%). Other respiratory manifestations have much lower percentages.

Parameter division of the studied group according to smoking habit was done. Expectoration was significantly higher among smokers compared to nonsmokers. Rest of parameters showed non significant difference between the studied groups (Results are not tabulated).

Table (2): Ventilatory function parameters among the studied workers.

Ventilatory function parameters		**Mean**	**Standard Deviation**	**Median**	**Minimum**	**Maximum**
FVC%		79.66	15.66	81.00	30.00	119.00
FEV_1%		77.16	16.01	78.50	28.00	124.00
FEV_1/FVC		0.79	0.12	0.81	0.33	0.99
MEF_{25}		79.53	35.11	75.00	12.00	222.00
MEF_{50}		72.15	26.10	71.00	10.00	166.00
PEF		56.54	27.57	53.00	13.00	444.00
MEF_{75}		59.86	20.38	59.00	9.00	124.00
MVV		61.67	21.58	61.00	11.00	127.00
		No		**%**		
FVC% <80%	Yes	157		44.7		
FEV_1%<80%	Yes	180		52.3		
FEV_1/FVC<70%	Yes	44		14.9		

FVC%: Forced vital capacity, FEV_1: Forced expiratory volume in first second, PEF: Peak expiratory flow rate, MEF: Maximal expiratory flow rate. MVV: Mean ventilatory ventilation.

Table 2 showed that 44.7% of studied workers showed restrictive pattern (FVC<80%). Obstructive pattern were found only in 14.9% of workers. Cut off levels were determined according to American thoracic society (ATS) guidelines (Pellegrino et al. 2005).

Table (3): Correlation between the duration of exposure to dust among brick workers and spirometric parameters.

Spirometric parameters	Duration of exposure		
	Correlation Coefficient	p value	No
FVC%	-0.033-	0.551	332
FEV_1 %	-0.057-	0.304	325
FEV_1/FVC	-0.049	0.415	278
MEF_{25}	-0.060-	0.278	332
MEF_{50}	-0.098-	0.073	333
PEF	-0.121-	**0.027***	333
MEF_{75}	-0.103-	0.060	333

FVC%: Forced vital capacity, FEV_1: forced expiratory volume in first second,

PEF: peak expiratory flow rate, MEF: maximal expiratory flow rate, *: Statistically significant.

Table 3 revealed non-significant correlation between the duration of exposure to dust among brick workers and spirometric parameters except for negative correlation with PEF (Table 3).

Table (4): Mean and SD of concentration of both respirable silica and dust.

Concentration	**Mean**	**SD**	**Minimum**	**Maximum**
Respirable silica (μg/m³)	27.61	36.23	6.50	306.00
Respirable dust (μg/m³)	644.12	836.35	22.40	6279.00

Table 4 showed that Mean and SD of respirable silica exceeds TLV-TWA of ACGIH and OSHA (27.61±36.23), while that of total dust still within permissible values (644.12±836.35).

In the current study 27 samples of respirable silica and 2 samples of respirable dust out of total 76 samples exceed TWA of ACGIH and OSHA. According to Egyptian Labor Law only 1 respirable silica sample exceeds the permissible limits.

Table (5): Mean and SD of concentration of both respirable silica and dust in ($\mu g/m^3$) according to different job description and exposure.

Respirable concentration		Mean	SD	Median	Minimum	Maximum
Handling raw green clay (Preparing, molding and stacking) clay (No = 34)	Silica	23.05	19.16	16.50	6.50	95.90
	Dust	507.50	585.72	395.85	22.40	3322.00
Preparing kiln, firing and unloading (No = 21)	Silica	30.50	47.22	15.10	7.22	226.70
	Dust	528.00	366.27	398.00	101.00	1401.00
Supervision (No = 3)	Silica	116.80	163.85	22.40	22.00	306.00
	Dust	2616.33	3182.36	1042.00	528.00	6279.00
Handling red cooked brick (No = 18)	Silica	29.45	12.42	26.90	12.60	54.40
	Dust	689.88	477.80	580.00	146.00	1822.00

Table 5 showed that highest Mean and SD of respirable silica and dust were reported among group of supervisors (116.80±163.85 and 2616.33±3182.36) respectively.

Comparison between respirable silica levels in different sectors was done for all groups except supervisors as it includes only three workers (It couldn't enter in statistical comparison). Statistically significant differences were found between compared groups (non-tabulated results).Post hoc test for concentration of respirable silica according to different compared job description and exposure were done and showed significance among workers of (handling cooked red brick than those handling raw material (preparing, molding and stacking) (non-tabulated results).

Discussion

Brick industry is a dusty operation that carries risk of exposure to silica (as a primary pollutant) and product of fuel combustion. The brick kilns in the current study had switched from mazot to natural gas with load reduction of PM, NO_2 and SO_2 which reached 96%, 72% and 24% respectively (Higazy et al. 2019).

The most prominent respiratory manifestation among Arab-Abosaeed brick kiln workers was shortness of breath (28.6%). Expectoration was the second common manifestation found in one fifth (19.4%) of the studied population and was significantly higher among smokers compared to nonsmokers (Table 1). Similarly, Raza and Ali (2021) reported shortness of breath in about one third of brick industry workers in Pakistan. Singh et al. (2020) in accordance with the current results, detected that dyspnea was present in 18.9% out of 270 brick industry workers. Also; Shaikh et al. (2012) study surveying 340 brick industry workers in Pakistan revealed irritative and allergic manifestations in the form of chronic cough and chronic phlegm in 22.4% and 21.2% respectively, of brick workers respectively. Higher respiratory illness manifestations were also found in many other studies (Torres-Duque et al. 2008; Raza and Ali 2021) on brick industries using HFO and garbage. Torres-Duque et al. (2008) attributed such obstructive and allergic manifestations reported in many studies on plants to solid fuel smoke rather than silica dust.

Assessment of pulmonary function tests using spirometry among the studied group detected restrictive impairment as a most frequent abnormality brick workers FVC<80 found in 44.7% of studied workers. Obstructive impairment defined as FEV1/FVC% < 70% was reported in 14.9% of workers. Though less than one sixth of the workers appeared to have obstruction; air flow limitation which is an early indication of obstructive diseases; scored (56.3%, 61.4% and 82.7%) of population in $MEF_{25}\%$, $MEF_{50}\%$ and $MEF_{75}\%$ respectively (Table 2).

Sanjel et al. (2016); in agreement with the present study confirmed the impact of silica in brick industries accusing silicosis of restricting pulmonary functions and breathing inefficiency. This can be explained by Sohrabi et al. (2022) who investigated the relations between occupational exposure to silica and chest manifestations and spirometry lung function and detected silica induced lung fibrosis and limitations of lung capacities.

Prasad et al. (2016), studied brick plants in Wardha district in India that used wood, recycled motor oil, coal, fuel oil, diesel, tires, trash and plastics as fuel sources. Spirometric assessment of their workers revealed obstructive impairment as the most prevalent impairment (in 21% of workers exposed >10 years). Restriction gets lower percentage (12%). Similarly, In Iraq Al-Shamma et al. (2009) studied five brick factories fired with wood and coal scored lower spiromeric parameters. Obstructive respiratory impairment predominated above restrictive impairment with significant elevated levels than control group. Dissimilarity to the current study may return to combustion of the mentioned dirty fuel that impact mainly air ways with resultant obstructive diseases as explained by authors.

In the present study non-significant correlation were found between duration of exposure and FVC or FEV_1/FVC (Table 3). Contrary to our results, Al-Shamma et al. (2009) notified negative correlation between pulmonary function values and duration of work which was not the case in this study. Rotation of workers between different sectors of plant with variable levels of dust and silica may alter such relation.

Environmental assessment revealed high level of respirable silica exposure (Mean±SD27.61±36.23mg/m3) exceeding latest guidelines (ACGIH 2010b; Aziz 2010) (Table 4). National Institute of Occupational Safety and Health (NIOSH) noted that lowering TLV-TWA standard for silica to less than 0.05 mg/m3 was mandatory to escape significant risk of silicosis (Mannetje et al. 2002). Similar results was detected by Salamon et al. (2021), in their study on occupational exposure to crystalline silica in artificial stone processing in Italy and reported silicosis and multiple respiratory affection on exposure to silica dust which was above ACGIH permissible limits. They found high levels of silica exposure at construction industries manually handling silica containing raw materials. Also, concentration of respirable silica was statistically significant among group exposed to raw material rich in respirable silica.

Comparison between concentration of respirable silica according to different job description and exposure were done and showed significant difference (non-tabulated results). Post hoc test detected elevation of respirable silica among workers handling red brick (steps after burning in kiln) than those handling raw clay (preparing, molding and stacking) (non-tabulated results). This agreed with a study done in Nepal by Sanjel et al. (2018) which stated that respirable silica is most prevalent in carrying and transporting red brick.

Conclusion and Recommendations

Workers in brick industries are still under high risk of occupational lung pathologies though better air quality was obtained by shifting to cleaner NG fuel in burning brick. While allergic manifestations and obstructive lung pattern showed lower percentages than studies on brick plants using HFO, restrictive lung affection still predominate. The environmental samples were exceeding the Egyptian permissible limits which lead to adverse respiratory effects. Special attention and more strict control measures should be followed not only to damp silica and dust particles exposure but also to revise permissible limits.

The limitations of the study include:

1. The study design: this is a descriptive analytical study designed to identify associations between the disease and the study group. This study does not identify the causes, explain the mechanisms behind these associations, or identify the underlying factors that contribute to the disease.

2. Assessment of lung function: though defining lung dysfunction as lung functional parameters (FEV_1/FVC ratio, FVC, and FEV_1) less than the lower limit of the normal value (LLN) (5th percentile in the reference age, sex, population, and height matched) is an epidemiological gold standard (recommended by the ATS, ERS, BTS societies), a 5% false positive risk usually resulted (Pellegrino et al. 2005). Additionally, test-related factors such as test variability, quality, frequency, and the follow-up duration may affect test used to determine pulmonary dysfunction (Pellegrino et al. 2005).

3- Chest X ray would be an important test to confirm silicosis but field visits, location of industries and administrative issues hindered radiography.

4-Post hoc test comparing different

sectors in plan did not include supervisor group due to small number of workers (only 3 ones).

Conflict of interest

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References

1. ACGIH (American Conference of Governmental Industrial Hygienists) (2010a): Threshold limits values for chemical substances and physical agents and biological exposure indices. In USA 200-219. https://www.acgih.org/science/tlv-bei-guidelines/
2. ACGIH (American Conference of Governmental Industrial Hygienists) (2010b): Silica, Crystalline: α-Quartz and Cristobalite. TLV Chemical Substances, 7th ed. https://www.acgih.org/silica-crystalline-a-quartz-and-cristobalite/
3. Al-Shamma YM, Dinana FM and Dosh BA (2009): Physiological study of the effect of employment in old brick factories on the lung function of their employees. J Environ Stud; 1(1):39-46.
4. Anwar TB, Behrose, B and Ahmed S (2018): Utilization of textile sludge and public health risk assessment in Bangladesh. SER; 28(5): 228-33.
5. Aziz HM, Ahmed SB and Saleh IA (2010): Respiratory hazards among Egyptian ceramics workers. Researcher; 2(6):65-73.
6. Beard JD, Thygerson SM, Olivares A, Tadje JE, Willis S, et al. (2022): Gaseous Air Pollutants and Respirable Crystalline Silica Inside and Outside Homes at Brick Kilns in Bhaktapur, Kathmandu Valley, Nepal. Int J Environ Res Public Health; 19(19); 12431.
7. Chan YH (2003 a): Biostatistics102: Quantitative Data – Parametric & Non-parametric Tests. Singapore Med J; 44 (8): 391-6.
8. Chan YH (2003b): Biostatistics 103: Qualitative Data –Tests of Independence. Singapore Med J; 44(10): 498-503.
9. Chan YH (2003c): Biostatistics 104: Correlational Analysis. Singapore Med J; 44(12): 614-9.
10. Ehrlich R, Akugizibwe P, Siegfried N and Rees D (2021): The association between silica exposure, silicosis and tuberculosis: a systematic review and meta-analysis. BMC Public Health; 21(1): 1-18.
11. Higazy M, Essa KS, Mubarak F, El-Sayed ES, Sallam AM, et al. (2019): Analytical study of Fuel switching from Heavy Fuel oil to Natural Gas in clay brick factories at Arab Abu saed, Greater Cairo. Sci Rep; 12; 9(1):1-0.
12. International Organization of Standardization (ISO) 16258-1 (2015): Workplace air-analysis of respirable crystalline silica by X-ray diffraction- part 1: direct-on-filter method. https://www.iso.org/standard/56034.html
13. Khan MW, Ali Y, De Felice F, Salman A and Petrillo A (2019): Impact of brick kilns industry on environment and human health in Pakistan.

Sci Total Environ; 15(678):383-9.

14. Kumar RS and Rajkumar P (2014): Characterization of minerals in air dust particles in the state of Tamilnadu, India through FTIR, XRD and SEM analyses. Infrared Phys Technol; 1(67):30-41.
15. Mannetje A, Steenland K, Attfield M, Boffetta P, Checkoway H et al. (2002): Exposure-response analysis and risk assessment for silica and silicosis mortality in a pooled analysis of six cohorts. Occup Environ Med; 59(11):723-8. DOI: https://doi.org/10.1136/oem.59.11.723
16. Miller MR (2005): ATS/ERS task force: standardization of spirometry. Eur Respir J; 26:319-38.
17. Mohamed SH, El-Ansary AL and Abd El-Aziz EM (2018): Determination of crystalline silica in respirable dust upon occupational exposure for Egyptian workers. Ind Health; 56(3):255-63.
18. OSHA (Occupational Safety and Health Administration) (2016): Occupational exposure to respirable crystalline silica. Final rule. Federal register; 25;81(58):16285-890. https://pubmed.ncbi.nlm.nih.gov/27017634.
19. Pellegrino R, Viegi G, Brusasco V, Crapo RO, Burgos F et al. (2005): Interpretative strategies for lung function tests. Eur Respir J; 1; 26(5):948-68.
20. Prasad MA, Nayak S, Mudey AB, Dhande N and Chandrakar D (2016): Assessment of health status of brick industry workers in Wardha district. JAIR; 5(1):1.
21. Raza A and Ali Z (2021): Impact of Air Pollution Generated by Brick Kilns on the Pulmonary Health of Workers. J Health Pollut; 11(31):210906.
22. Salamon F, Martinelli A, Vianello L, Bizzotto R, Gottardo O et al. (2021): Occupational exposure to crystalline silica in artificial stone processing. J Occup Environ Hyg; 18(12), 547-54.
23. Sanjel S, Khanal SN, Thygerson SM, Carter W, Johnston JD et al. (2018): Exposure to respirable silica among clay brick workers in Kathmandu valley, Nepal. Arch Environ Occup Health; 2; 73(6):347-50.
24. Sanjel S, Thygerson, SM, Khanal, SN and Joshi SK (2016): Environmental and Occupational Pollutants and Their Effects on Health among Brick Kiln Workers. OJSST; 6(4):81-98.
25. Shaikh S, Nafees AA, Khetpal V, Jamali AA, Arain AM, et al. (2012): Respiratory symptoms and illnesses among brick kiln workers: a cross sectional study from rural districts of Pakistan. BMC Public Health; 12(1):1-6.
26. Singh L, Mukherjee S, Bhattacharyya N, Mukherjee M and Majumdar S (2020) Respiratory Morbidities Related to the Concentration of Airborne Particulate Matter among Brick Kiln Workers-A Cross Sectional Study in Charhi Block, Jharkhand. International Journal of Research and Review (IJRR); 7(2):449-55.
27. Sohrabi Y, Sabet S, Yousefinejad S, Rahimian F, Aryaie M et al. (2022): Pulmonary function and respiratory symptoms in workers exposed to respirable silica dust: A historical cohort study .Heliyon;8 (11): e11642.