Study of Silico-Tuberculosis Among Workers in Pottery Craft Manufacturing Area

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Abstract

Background: El-Fawakheer Pottery craft workers are more prone to occupational exposure to respirable silica. Such exposure could lead to various health hazards including respiratory, musculoskeletal, skin, gastrointestinal and neurological disorders. **Aim of study:** Assessment of silicosis and silico-tuberculosis among pottery workers and focus on the association between silicosis and the development of tuberculosis in pottery industry exposed workers. **Subject and methods:** Analytical Cross-sectional study was done, comprising 185 workers out of 200 individuals working in pottery Clay Crafts who agreed to participate in the study. The workers were subjected to full clinical examination, laboratory investigations included tuberculin skin test, plain chest x ray and ventilatory function tests. Bulk Sample mineralogy & environmental samples measurements for respirable dust and respirable silica, in addition to SO_2, CO, CO_2, NO_2, VOCs and PM_{10}. **Results**: showed that more than half of the studied workers complained from chest, musculoskeletal, dermatological, GIT and nervous problems with 38.3, 16.2, 10.2, 4.3 and 3.7 % frequency respectively. Tuberculin test was positive in four workers with chest x-ray opacities. According to the Egyptian Ministerial Decree 211 for the year 2003 "Limits of workplace pollutants" as promulgated by the Egyptian labour law number 12 for the year 2003, silica dust exposure levels exceeded the accepted limit in 5 samples out of 82 samples while in only one sample the respirable dust exceeded the accepted limit. Results showed that there is statistically significant difference of PM10, CO, CO_2 between the different places of sampling. **Conclusion:** Pottery craft workers have high risk for development of silicosis and subsequent pulmonary Silico-tuberculosis.

Keywords: pottery crafts, silica, pulmonary Silico-tuberculosis, chest x ray, tuberculin test.

Introduction

Ancient Egyptian pottery began 5000 BC, having spread from the Levant. There were many distinct phases of development in pottery, with very sophisticated wares being produced by the Naqada III period, dating approximately 3200 to 3000 BC. During the early Mediterranean civilizations of the Fertile Crescent, Egypt developed a unique non-clay-based ceramic which has come to be called Egyptian faience. During the Umayyad Caliphate of Islam, Egypt was a link between early center of Islam in the Near East and Iberia which led to the impressive style of pottery **(1).**

Many areas in Egypt have great expertise in pottery making because of the high connection between Pottery and Egyptian culture. Nile clay contains greater amounts of silica and can be fired at lower temperatures, around 700 to 800°C. Many Centers of Pottery places are located in various places in Egypt nowadays (Aswan Governorate (Nubia), Qena Governorate, Assiut Governorate, Al-Wadi Al-Gadid and Sinai. Qena in Upper-Egypt is very famous for pottery making especially the "Olla" as well as (Tunis) Village in Al fayoum **(2)**.

In the '70s a Swiss artist "Evelyne Porret" visited Tunis village and saw the kids playing with the mud making funny shapes. Being a pottery artist herself and inspired by Ramsis Wisa Wassef's Harraneya Center, she decided to settle in the village and teach the children the art of pottery. She established a school for pottery in the village, and the village's products participate in international galleries and competitions **(3).**

Al-Fustat, Old Cairo, is a center for handicrafts in general and especially Pottery. In the same area, there is "Al-Fustat pottery center" which is mainly concerned with developing this art through multiple initiatives and workshops **(4).**

It was found that the work conditions in pottery clay area were rather dusty with much pollution from coal in the kilns and from clay used for pottery making. The greatest health risk is the potential to develop silicosis from the long-term exposure to crystalline silica **(5).**

Reduced exposure to silica has a marked effect on Tuberculosis (TB) control. Silica exposure can increase the risk of TB even in the absence of silicosis. Experimental studies showed that silica impairs the function of alveolar macrophages, and severe exposure causes macrophage apoptosis. These findings are consistent with observations that the incidence of pulmonary Silico-tuberculosis in dust-exposed workers is higher even in those without established silicosis **(6).**

Tuberculosis (TB) is among the most prevalent public health dilemmas of the 21st century **(7).**

The study aimed for assessment of silicosis and pulmonary silico-tuberculosis among pottery workers, focusing on the association between silicosis and the development of tuberculosis in pottery industry exposed workers.

Subjects and Methods

The study was performed in El-Fawakheer Clay Crafts (Pottery) manufacturing area. In the studied area, there are eighty kilns, ten uses wood and electricity as a fuel, five use mixture of wood and natural gas and the rest use wood and garbage as a fuel. Due to covid 19 pandemic restrictions and limitations at the site for environmental sampling, 24 kilns employing 200 workers were functioning at the time of the study and whom owners accepted to participate. In this study, 24 kilns four use wood and electricity as a fuel, two use mixture of wood and natural gas and the rest use wood and garbage as a fuel.

Prior to this study, written informed consent from the workers of the 24 kilns was obtained after explaining to them the aim of the study. Strict confidentiality was carried out through sample collection, coding, testing and recording of the results. Descriptive Cross-sectional study comprised 185 workers out of the 200 workers, who accepted to be involved in the study, in the selected 24 kilns in pottery Clay Crafts.

Inclusion criteria:

- Individuals working in pottery clay craft at El-Fawakheer Area
- Any age
- Both gender

Exclusion criteria:

- Individuals not in area of interest of the study.
- Previous history of tuberculosis or treatment of tuberculosis before joining the work
- Previous history of occupational exposure to dust other than in the area of study

The workers were subjected to the following:

- Questionnaire
- Clinical examination
- Laboratory tests: Tuberculin and ventilatory functions tests
- Plain X-ray chest (PA view).

Environmental study including:

- **Quantitative mineralogy by X-ray diffraction.**
- Respirable dust and silica analysis.

- Air pollutants measurements for **SO_2, CO, CO_2, NO_2, VOCs and PM_{10}**

Questionnaire:

Workers were interviewed according to a previously prepared questionnaire comprising full present and past occupational history, duration of exposure, and nature of job in the pottery. The questionnaire comprised complaint at the time of the study, past and present medical history, stressing on the condition of the chest. The use of personnel protective equipment especially respiratory protection equipment was also recorded. (Annex 1). The questionnaire was administrated a to all workers included in the study

Clinical examination:

General and local examination stressing on the condition of the chest, skin and heart.

Laboratory investigations:

Tuberculin skin test using Mantoux technique:

A standard dose of 5 tuberculin units (TU - 0.1 ml) was injected intradermal (between the layers of dermis) on the flexor surface of the left forearm, mid-way between elbow and wrist. The injection was made with a tuberculin syringe, with the needle bevel facing upward. When placed correctly, injection produce a pale wheal of the skin, 6 to 10 mm in diameter. The result of the test was read after 48 hours **(8).**

The results of this test were interpreted carefully. The person's medical risk factors determine the size of induration the result is positive (5 mm, 10 mm, or 15 mm) **(9).**

Plain Chest X-ray (PA):

Plain post anterior chest x-ray was done at the pottery workshop site to all workers using Browiner Portable digital x ray Generator. Chest radiographs were obtained at the work site and all X-rays were examined by Radiology staff of Radiology Department of Cairo university and three expert occupational readers according to the ILO pneumoconiosis guidelines.

Basic Pulmonary Function testing (Spirometry):

The Spirobank II Spirometer used in the study is designed to provide exceptional accuracy. This spirometer measures a wide range of respiratory parameters for versatility and user accommodation. Each spirometer includes the innovative Winspiro PRO PC software enabling easy tracking and recording of the measured data for storage.

Before the spirometry test, each worker was asked about illnesses, smoking and medication used. Each worker was asked to take a deep breath and then blow out as strongly and as fast as they could for at least 6 seconds until complete exhalation.

Nose clips were used to avoid any air leakage and disposable mouthpieces were used to preserve good hygiene conditions and prevent any spread of infection. Workers were told to seal their lips around the mouthpiece before blowing out.

The test was repeated 3 times and the best reading was recorded. Subjects were tested for their Forced Vital Capacity (FVC % pred), Forced Expiratory Volume in the 1^{st} Second (FEV1 % pred), FEV1/FVC ratio as a percent from normal predicted values, Peak Expiratory Flow Rate (PEFR). Normal predicted values were calculated by giving data of participating subjects (age, gender, weight, height and BMI).

Environmental study:

Bulk samples mineralogy and environmental samples measurements for respirable dust and silica were done using X-ray powder diffraction, the mineralogical composition of a finely milled sample can be determined quantitatively. During the analysis, the powdered sample is exposed to 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).

Practically, a sample is continuous irradiated with X-rays (usually this is Cu-Kalpha radiation) over an extensive angular range and a detector is positioned so it can detect the reflected constructive interference. In this way, a diffraction pattern is obtained with on the X-axis the angular range ("2Thèta) from typically 2° to 75° and on the Y-axis the intensity that the detector has picked up at each measured angle.

Diffraction patterns of the samples with an indication of the main minerals that contribute to the most important reflections. The most important minerals are indicated: Quartz (Q), Kaolinite (K), Gypsum (G), Hematite (H), Feldspar: both Alkali feldspar and Plagioclase (F), Calcite (C) and 2:1 phyllosilicates (2:1).

Quantitative mineralogy by X-ray diffraction

The analysis consists of the bulk mineralogical analysis of the sample by X-ray diffraction.

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 handled 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 Cu K-alfa radiation. The subsequent quantification was performed by an in-house method based on the Rietveld method. Diffraction patterns of the sample with an indication of the main minerals that contribute to the most important reflections.

Respirable dust fraction and silica:

During 12 visits, eighty-two air samples were taken at the respirable breathing zone of the workers during the following steps of the industrial process:

- Preparing clay (n = 9)
- Molding (n = 8)
- Screening and shaping (n =10)
- Loading kiln (n = 10)
- Preparing kiln (n = 13)
- Firing kiln (n = 16)
- Unloading kiln and stacking (n = 9)
- Others: painting and glazing pottery (n = 7)

Air pollutants (SO2, CO, CO2, NO2, VOCs and PM10) SO2, CO, CO2, NO2, VOCs and PM10 were measured over 3 visits.

Statistical analysis

Data obtained from the study was coded and entered using the statistical package SPSS version 15. The mean values, standard deviation (SD) and ranges were then estimated for quantitative variables. As for the qualitative variables, the frequency distribution was calculated.

Comparisons between two groups were done using Chi square (χ^2) test for qualitative variables and the independent simple t-test as well as the analysis of variance (ANOVA test) followed by Post Hoc test for normally distributed quantitative variables at P value 0.05.

Correlations and regressions were used to test for the presence of linear relations between quantitative variables. P-values less than 0.05 and less than 0.001 were considered statistically significant.

In linear regression analysis, Beta coefficient represents odd’s ratio whose value if more than 1 means that the independent variable is a risk for the dependent one.

Results

Table (1): Distribution of some demographic and working condition of the studied group.

	Number (185)	**%**
Gender		
Male	181	**97.8**
Female	4	2.2
Age		
Below 18	19	10.3
Above 18	**166**	89.7
Place of work		
Combined Pottery clay and fiber glass	159	**85.9**
Pottery clay	16	8.6
Fiber glass	10	5.4
Smoking habit	117	**63.2**
Cigarettes	75	**64.1**
Shisha	30	25.6
Combined	12	10.2
Drugs intake	24	**12.9**
Alcohol	2	8.3
Tramadol	8	33.3
Cannabis	13	54.1
Others(benzodiazepines)	1	4.1
Combined	2	8.3
Duration of work (years)		
<10	67	**36.2**
10-<20	47	25.4
20-<30	23	12.4
30-<40	34	18.4
40-<50	9	4.9
≥50	5	2.7
Types fuel		
Wood only	**124**	67.02
Wood + electricity	59	31.89
Wood + natural gas	2	1.08
Use of respiratory PPE	**4**	2.16

Table (1): Mean and standard deviation of age, duration of employment, vital signs and smoking status of the studied group

97.8% of the studied population were males. More than half of them were smokers (63.2%), 64.1% of smokers were cigarette smokers. 12.9% of the studied group took drugs. Combined pottery and fiber glass was the commonest place of work where 86% of the studied group worked in. About one third (36%) of studied participants worked for less than 10 years. Mean + SD of systolic blood pressure was 131.14 + 20.53 while mean + SD of diastolic blood pressure was 81 + 13.309. Mean and SD of the number of smoked cigarette pack/year was 26.18 + 49.126.

Table (2): Distribution of workers according to main complaint and medical history.

C/O and medical history	No. (n = 185)	% Absolute
1. Complaint	**135**	**72.9**
• Chest	71	38.3
• Musculoskeletal problems	**30**	16.2
• GIT problem	8	4.3
• Nervous	7	3.7
• Skin problems (contact dermatitis)	19	10.2
2. Medical history	**102**	**55.135**
• Asthma	13	**7.0**
• Hypertension	21	**11.3**
• Diabetes	36	**19.4**
• Cancer	4	2.1
• Others (like ischemic heart diseases, autoimmune diseases)	5	2.7
• Combined (more than one of the diseases above)	23	12.4

More than half of the studied workers complained from chest, musculoskeletal, dermatological, GIT problem and Nervous problems with 38.3, 16.2, 10.2, 4.3 and 3.7 % frequency respectively. 55% of the studied population had past medical history, most commonly diabetes, hypertension and asthma with prevalence of 19.4, 11.3 and 7 % respectively.

Table (3): Distribution of workers according to general, chest examination and tuberculin test (total no 185)

Examination	No.	%
1. General examination		
• Clubbing	3	1.6
• Cyanosis	1	0.5
• Congested neck veins	1	0.5
2. Chest symptoms		
• **Shortness of breath**		
• On mild exertion	24	12.9
• Moderate exertion	9	4.8
• Severe exertion	1	0.5
• **Cough**	**20**	**10.8**
• **Wheezes**	**17**	**9.1**
• **Chest pain**	**20**	**10.8**
• **Symptoms suggestive of tuberculosis (night fever and night sweat)**	**3**	**1.6**
3. Auscultation		
• Diminished breath sounds (bilateral)	1	0.5
• Diminished breath sounds (on 1 side)	6	3.2
• Harsh vesicular breathing with prolonged expiration	32	17.2
• Rhonchi	13	7.0
• Crepitations	1	0.5
• Combined	7	3.7
4-Positive Tuberculin Skin Test	**4**	**2.1**

Main chest complaints of the workers were shortness of breath followed by cough and chest pain then wheezes with 18.2, 10.8, 10.8% and 9.1% respectively. On auscultation harsh vesicular breathing with prolonged expiration and rhonchi were predominately found among workers (17.2 and 7% respectively). Tuberculin test was positive in only 4 workers among the studied group.

Table (4): Number and percent distribution of symptoms and signs of studied workers according to affected joint (total no 185)

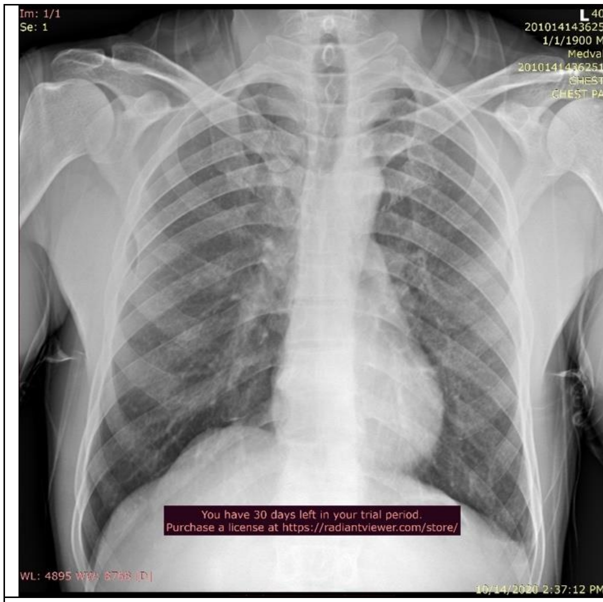
Musculoskeletal	No	Absolute %
Affected joints (symptoms)	**30**	**16.2**
Wrist and hands	7	3.7
Lower back	16	8.6
Upper back	14	7.5
Knees	10	5.4
Neck	8	4.3
Shoulder	9	4.8
Elbows	5	2.7
Feet and ankle	11	5.9
Hip	4	2.1
Combined joints (more than one joint)	8	4.3
Signs		
Crepitus	15	8.1
Tenderness	3	1.6
Limitation of movement	18	9.7
Combined (more than one of the above signs)	9	4.8

On examination the most frequent signs among the studied workers were limitation of movement followed by crepitus (9.7% and 8.1%) respectively. and the most frequently affected joints were the lower back followed by upper back, feet and ankles then knees (8.6 ,7.5%, 5.9% and 5.4% respectively).

Table (5): Number and percent distribution of the plain chest x-ray findings among the studied population (n=185)

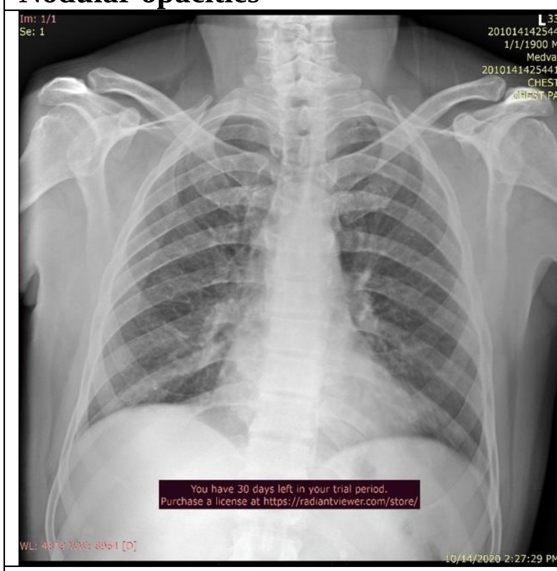
Chest x-ray findings	No.	%
Normal	98	52.9
Nodular opacities	**12**	6.5
Irregular opacities	**26**	14.1
Fibronodular	**16**	8.6
Plaques	**5**	2.7
Pleural Thickening	4	2.2
Granuloma	5	2.7
Effusion	1	0.5
Cardiomegaly	13	7.0
Post sternotomy	1	0.5
Increased broncho-vascular markings	13	7.0
Atelectasis	4	2.2
Obliterated Costa-phrenic angle	2	1.1
Emphysema	3	1.6
Honey combing	2	1.1
Bronchiectasis	2	1.1
Raised right copula of the diaphragm	2	1.1
Bones deformities	16	8.6
Combined	27	14.5

Plain chest X-ray showed that **irregular opacities** were the most common reported radiological opacities among the different type of opacities followed by fibro nodular then nodular opacities (14.1 %, 8.6%, 6.5% respectively). Granuloma were reported in 2.7% of the studied group. Bone deformities and cardiomegaly were observed (8.6 % and 7 % respectively). Pleural plaques represented in 2.7% while pleural thickening represented in 2.2%.

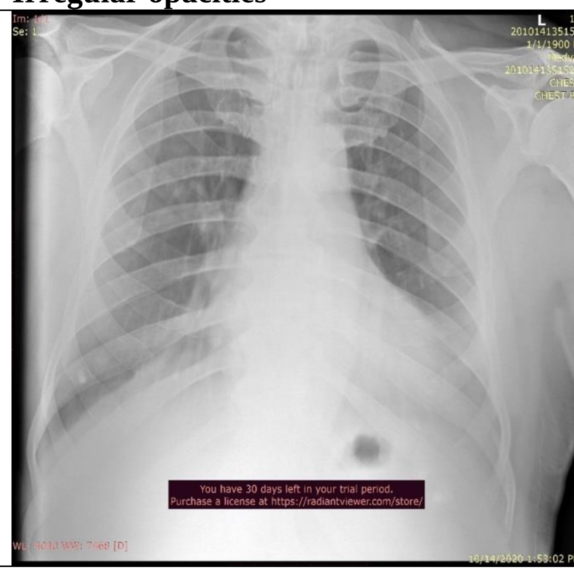


Nodular opacities

Irregular opacities



Fibro nodular opacities



Old granulomatous lesion

Figure 1: Examples of different opacities in chest x ray among studied group

Table (6): Frequency distribution the studied group chest x ray suggestive of silicosis, asbestosis and tuberculosis (granuloma, nodular, fibro nodular and irregular opacities) according to tuberculin skin test.

	Tuberculin skin test			
	Positive		**Negative**	
	number	**%**	**Number**	**%**
Granuloma	0	0	5	2.7
Nodular and fibro nodular opacities	1	0.54	27	14.5
Irregular opacities	1	0.54	25	13.5

Two of tuberculin skin test positive workers were found to have nodular, fibro nodular and irregular opacities. Workers with chest x-ray granulomas were all tuberculin skin test negative

Table (7): Correlation coefficient between FVC%, FEV1 and work extent, age and smoking.

	Partial correlation (r) Work extent life time in hours	**Partial correlation (r) of age years**	**Partial correlation coefficient r of smokers**
FVC%	**- 0.165**	**- 0.163**	**n.s.**
FEV_1%	**n.s.**	**- 0.187**	**- 0.202**

Calculation of total lifetime working hours

- Work Extent in hours = A X B X C
  - Duration of work (Hours/day)
  - Duration of work (days/week)
  - Duration of work (years) X 52 weeks

- Coefficient of determination (R^2) = 0.076 ANOVA test p = 0.001

Prediction equation for FVC%

FVC% = 86.3 - 0.17 X work extent - 0.168 X Age in years

The more the working hours the lower the value of FVC% than 86.3%

Also, the older the worker the lower the value of FVC% than 86.3%

- Coefficient of determination (R^2) = 0.074 ANOVA test p =0.001

Prediction equation for FEV1%

FEV1% = 86.75 - 0.201 X smoking - 0.157 X Age in years

The smokers gave a lower value of FEV1% than 86.75% (lower than non-smokers). However, the older the worker the lower the value of FEV1% than 86.75%.

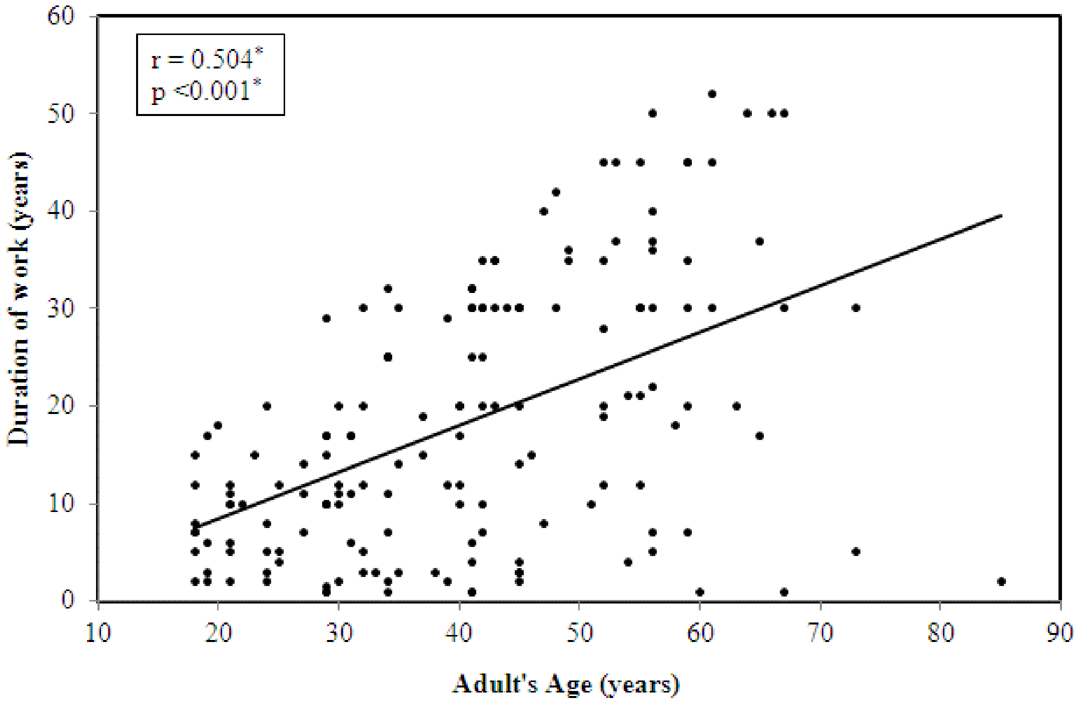


Figure (2): Relation between duration of work with age (years) for adult group

r: Pearson coefficient
*: Statistically significant at $p \leq 0.05$

As regards the correlation between duration of work with age (years) for adult group, it was found that as the age increases the duration of work increases and reach the level of significance ($p< 0.001$).

Comparison of the different studied parameters between child and juvenile and adult showed the following:

- No statistical significance of the studied group was found between different working conditions (type of fuel, place of work and use of PPEs) in different age category (annex 2).
- No statistical significance was found between the examined adult and child workers concerning the various parameters (annex 3).
- There is no statistical significance found between various chest X-ray findings among the examined adult and child workers except for cardiomegaly ($p = 0.032$) which is more among child than adult (annex 4).
- There is statistical significance between adult and child workers among the studied group as regards FEV_1% (Annex 5).

Table (8): Quantitative mineralogical composition of the samples (in weight percentages of the identified minerals):

Mineral	Theoretical formula	Bulk sample potteries – mixed raw materials before molding
Silicates		
Quartz	SiO2	30,0
Albite/Plagioclase	(Ca, Na) (Si, Al)4O8	12,2
Alkali-feldspar	(K, Na) (Si, Al)4O8	8,3
Kaolinite	Al2Si2O5(OH)4	18,2
2:1 Al phyllosilicates (Muscovite and “clays”)	(K, H3O) (Al, Mg, Fe)2 (Si, Al)4O10[(OH)2, (H2 O)]	26,2
Halides		
Halite	NaCl	0.9
Carbonates		
Calcite	CaCO3	1,4
Sulphates		
Gypsum	CaSO4.2H2O	2.7
Oxides/Hydroxides		
Anatase	TiO2	0,7
Hematite	Fe2O3	2,0
Goethite	Fe O (OH)	0,9
Sulphides		
Pyrite	FeS2	0.1

The samples are mainly composed of Quartz (30) and phyllosilicates. These phyllosilicates are Kaolinite (18.2%) and “2:1 Al phyllosilicates” (26.2) the latter group may be composed of Illite, Smectite (Montmorillonite-type) and/or interstratified min19-H0018erals. Other minerals that occur in the sample are: Albite/Plagioclase (12.2%), Alkali-feldspar (8.3%), Calcite (1.4%), Anatase (0.7%), Hematite (2.0%) and Goethite (0.9%). In the brick kilns sample, also Halite (0.9%), Gypsum (2.7%) and Pyrite (0.1%) were identified.

Table (9): Flow rate and run time of respirable silica and respirable dust of the studied samples in relation to job description

Type of Job	Flow rate (ml/min) X + SD	Run time X + SD
Preparing clay (n = 9)	2145.9 ± 45.7	156.4 ± 20.2
Molding (n = 8)	2166.1 ± 74.3	171 ± 18.2
Screening and shaping (n = 10)	2164.6 ± 73	139.9 ± 25.5
Loading kiln (n = 10)	2173.1 ± 36.7	158.3 ± 17.9
Preparing kiln (n = 13)	2160.7 ± 55.4	179.3 ± 9.5
Firing kiln (n = 16)	2128.1 ± 49.2	140.1 ± 22.3
Unloading kiln and stacking (n = 9)	2178.7 ± 71.1	148.6 ± 19.4
Others: painting and glazing pottery (n = 7)	2150.6 ± 28.6	139.4 ± 16.9
Fiber glass mixing and glazing (n = 6)	2107 ± 74.4	148.3 ± 9.2
Test of significance P value	**F = 1.382** **n.s.**	**F = 6.310*** **<0.05***

F: ANOVA test *****: Statistically significant at $p \leq 0.05$

n = number of samples **n.s.:** non-significant

There is statistical significance among run time of respirable silica and dust among studied sample.

Table (10): Post Hoc Tests for both silica and dust exposure (Run time) in relation to job description

Job description of pottery in silica exposure (Run time)	Preparing clay	Molding	Screening and shaping	Loading kiln	Preparing kiln	Firing kiln	Unloading kiln and stacking	Others: painting and glazing pottery	Fiber glass mixing and glazing
Preparing clay (n=9)									
Molding (n=8)	0.807								
Screening and shaping (n=10)	0.607	0.022*							
Loading kiln (n=10)	1.000	0.886	0.425						
Preparing kiln (n=13)	0.132	0.986	<0.001*	0.182					
Firing kiln (n=16)	0.494	0.009*	1.000	0.301	<0.001*				
Unloading kiln and stacking (n=9)	0.993	0.271	0.985	0.968	0.009*	0.976			
Others: painting and glazing pottery (n=7)	0.686	0.044*	1.000	0.525	0.001*	1.000	0.988		
Fiber glass mixing and glazing (n=6)	0.996	0.397	0.994	0.982	0.034*s	0.992	1.000	0.995	

z: **F for One way ANOVA test** *: Statistically significant at $p \leq 0.05$

The significance was between screeping and shaping, molding and preparing kiln.

Table (11): Threshold level values of the studied samples of both respirable silica and respirable dust according to site of sampling

Job description	samples of abnormal level for silica	samples of abnormal level for respirable dust
Preparing clay (n = 9)	1 (0.36 mg/m³)	0
Molding (n = 8)	2 (0.2mg/m³) and (1.2 mg/m³)	1 (10.5 mg/m³)
Screening and shaping (n =10)	0	0
Loading kiln (n = 10)	0	0
Preparing kiln (n = 13)	0	0
Firing kiln (n = 16)	1 (0.28 mg/m³)	0
Unloading kiln and stacking (n = 9)	1 (0.42 mg/m³)	0
Others: painting and glazing pottery (n = 7)	0	0
Fiber glass mixing and glazing (n = 6)	0	0
TLVs	silica level 0.05 (mg/m³)	dust level 3 (mg/m³)

It was found that silica exposure level exceeded the accepted limit according to the Ministerial Decree 211 for the year 2003 “Limits of workplace pollutants” as promulgated by the Egyptian labour law number 12 for the year 2003 by 5 samples out of 82 samples analyzed while dust exposure level exceeded the accepted limit in one sample.

Table (12): Mean values + SD of PM_{10} in mgm3, CO, CO2, SO2, NO2, and VOCs in ppm elicited in different places in and outside workshops.

	Site of measure (no of samples)	Range $\bar{x}$ + SD					
		PM_{10} in mg/m^3	**CO in ppm**	**CO_2 in ppm**	**SO_2 in ppm**	**NO_2 in ppm**	**VOCs in ppm**
TLVs[1]		**<3 (inhalable) <10 (total)**	**25**	**5,000**	**0.25**	**0.2**	**Not present as a group**
Indoors	**Feeding of oven (5)**	1.70 ± 0.59	8.20 ± 5.93	420.2 ± 30.70	0.65 ± 0.48	0.30±0.17	0
	Behind/ besides the Oven (9)	0.92 ± 0.50	8.20 ± 7.52	410.7 ± 42.39	1.12 ± 1.10	0.29 ± 0.17	94.50 ± 133.77
	Working area (6)	1.05 ± 0.49	4.50 ± 6.25	411.0 ± 18.83	5.37 ± 8.12	0.25 ± 0.16	287.0
Outdoor	**Outdoor (5)**	0.94 ± 0.66	2.18 ± 4.38	390.4 ± 27.70	0.06 ± 0.13	0.18 ± 0.12	0
	Infront of oven (6)	0.36 ±0.29	1.67 ± 1.53	385.0 ± 87.18	0.10 ± 0.10	0.20 ± 0.15	0
Natural gas	**Before and during feeding (3)**	0.46 ± 0.23	1.0 ± 1.0	386.7 ± 33.29	0.07 ± 0.06	0.15 ± 0.05	0
Mixed Fiber glass and pottery	**Painting and glazing (4)**	0.41 ± 0.09	0.0 ± 0.0	411.3 ± 30.92	0.08 ± 0.05	0.42 ± 0.21	445.5 ± 381.0
Fiber glass	**Working area (3)**	0.40 ± 0.14	0.20 ± 0.35	365.0 ± 9.90	0.0 ± 0.0	0.11 ± 0.01	39.0 ± 33.29
wood fuel Ovens	**Stopped oven (7)**	0.60 ± 0.57	0.08 ± 0.20	329.33 ± 33.30	0.0 ± 0.0	0.11 ± 0.01	0.0 ± 0.0
	Manual working (2)	0.48 ± 0.20	0	366.50 ± 2.12	0	0.11 ± 0.01	0
Without oven	**Painting workshop (3)**	0.08 ± 0.06	0	366.0 ± 10.39	0	0.12 ± 0.00	13.0
Garden between workshops	**Garden center**	0.023	0.0	378	0	0.098	0
Electric oven	**In front of oven (3)**	0.36 ± 0.29	1.67 ± 1.53	385.0 ± 87.18	0.10 ± 0.10	0.20 ± 0.15	2.0
F (p)		**3.729*** <0.05*	**2.275*** <0.05*	**2.688*** <0.05*	**1.377** n.s.	**2.164*** <0.05*	**1.438** n.s.

F: **F for One way ANOVA test**, Pair wise comparison between each 2 groups was done using **Post Hoc Test (Tukey)**
*: Statistically significant at $p \leq 0.05$
N = number of samples for each process n.s.: non-significant.

Results show that PM10, CO, CO_2 and NO_2 were statistically significant between the different places of sampling

The highest PM_{10} in mgm3 mean was in the workshops during feeding of oven and least during painting and glazing and the highest CO in ppm mean was during feeding of oven and least among oven using wood, painting workshops and garden.

Also **Results** show that the highest CO2 in ppm mean was during feeding of ovens and the highest SO2 in ppm mean was in the indoor working area.

[1] According to the Egyptian Ministerial Decree #211 for 2003

Finally, **Results** shows that the highest NO_2 in ppm mean was in the mixed fiber glass and pottery and the highest VOCs in ppm mean was in mixed fiber glass and pottery.

Table (13): Post Hoc Tests for PM10 in mgm3 air pollutants elicited in the various types of workshops

PM10	Feeding of Oven	Behind/ besides the Oven	Working area	Electric Oven	Natural gas	Mixed Fiber glass and pottery	Fiber glass	Outdoors	Stopped oven	Manual working	Without oven
Feeding of Oven											
Behind/ besides the Oven	0.151										
Working area	0.471	1.000									
Electric Oven	**0.015***	0.779	0.617								
Natural gas	**0.034***	0.922	0.803	1.000							
Mixed Fiber glass and pottery	**0.009***	0.774	0.601	1.000	1.000						
Fiber glass	**0.020***	0.840	0.687	1.000	1.000	1.000					
Outdoors	0.310	1.000	1.000	0.844	0.949	0.852	0.890				
Stopped oven	**0.012***	0.953	0.832	1.000	1.000	1.000	1.000	0.978			
Manual working	0.111	0.979	0.923	1.000	1.000	1.000	1.000	0.985	1.000		
Without oven	**0.001***	0.243	0.161	1.000	0.995	0.997	0.999	0.344	0.869	0.997	

*: Statistically significant at $p \leq 0.05$

Post hoc test revealed that feeding of oven was the most common step where PM10 is statistically significant among other steps.

Table (14): Post Hoc Tests for (CO in ppm) air pollutants elicited in the various types of workshops

CO	Feeding of Oven	Behind/ besides the Oven	Working area	Electric Oven	Natural gas	Mixed Fiber glass and pottery	Fiber glass	Outdoors	Stopped oven	Manual working	Without oven
Feeding of Oven											
Behind/ besides the Oven	0.968										
Working area	0.734	0.922									
Electric Oven	0.612	0.621	0.999								
Natural gas	0.309	0.484	0.993	1.000							
Mixed Fiber glass and pottery	0.463	0.179	0.925	1.000	1.000						
Fiber glass	0.659	0.334	0.969	1.000	1.000	1.000					
Outdoors	0.198	0.485	0.999	1.000	1.000	1.000	1.000				
Stopped oven	0.620	**0.082***	0.874	1.000	1.000	1.000	1.000	1.000			
Manual working	0.427	0.526	0.984	1.000	1.000	1.000	1.000	1.000	1.000		
Without oven	0.968	0.301	0.958	1.000	1.000	1.000	1.000	1.000	1.000	1.000	

*: Statistically significant at $p \leq 0.05$

Post hoc test revealed that stopping of the oven after the end of the firing process was the most common step where CO is statistically significant among other steps.

Table (15): Post Hoc Tests for (CO2 in ppm) air pollutants elicited in the various types of workshops

CO2	Feeding of Oven	Behind/ besides the Oven	Working area	Electric Oven	Natural gas	Mixed Fiber glass and pottery	Fiber glass	Outdoors	Stopped oven	Manual working	Without oven
Feeding of Oven											
Behind/ besides the Oven	1.000										
Working area	1.000	1.000									
Electric Oven	0.959	0.992	0.994								
Natural gas	0.970	0.995	0.996	1.000							
Mixed Fiber glass and pottery	1.000	1.000	1.000	0.997	0.998						
Fiber glass	0.767	0.871	0.894	1.000	1.000	0.922					
Outdoors	0.964	0.995	0.997	1.000	1.000	0.998	0.999				
Stopped oven	0.008*	0.006*	0.016*	0.545	0.503	0.044	0.979	0.210			
Manual working	0.794	0.892	0.912	1.000	1.000	0.936	1.000	0.999	0.972		
Without oven	0.626	0.750	0.802	1.000	1.000	0.861	1.000	0.997	0.935	1.000	

*: Statistically significant at $p \leq 0.05$

Post hoc test revealed that stopping of the oven after the end of process was the most common step where CO2 is statistically significant among other steps.

Table (16): Post Hoc Tests for (NO2 in ppm) air pollutants elicited in the various types of workshops

NO2	Feeding of Oven	Behind/ besides the Oven	Working area	Electric Oven	Natural gas	Mixed Fiber glass and pottery	Fiber glass	Outdoors	Stopped oven	Manual working	Without oven
Feeding of Oven											
Behind/ besides the Oven	1.000										
Working area	1.000	1.000									
Electric Oven	0.997	0.996	1.000								
Natural gas	0.930	0.900	0.992	1.000							
Mixed Fiber glass and pottery	0.960	0.861	0.656	0.544	0.259						
Fiber glass	0.784	0.705	0.935	0.999	1.000	0.133					
Outdoors	0.956	0.924	0.998	1.000	1.000	0.230	1.000				
Stopped oven	0.549	0.361	0.774	0.996	1.000	**0.033***	1.000	0.999			
Manual working	0.869	0.835	0.968	1.000	1.000	0.247	1.000	1.000	1.000		
Without oven	0.800	0.725	0.943	0.999	1.000	0.142	1.000	1.000	1.000	1.000	

*: Statistically significant at $p \leq 0.05$

Post hoc test revealed that stopping the oven especially in mixed fiberglass workshops after the end of process was the most common step where NO_2 is statistically significant among other steps.
Sixty percent of patient had occlusive lesions. And a total of 26.6 %were classified as Rutherford IV (Table 1). Indications for intervention were either life style limiting claudication (Rutherford III) or limb salvage (Rutherford IV/V).

Discussion

El-Fawakheer Clay Crafts (Pottery) manufacturing area is a part of the Old Cairo District. It is one of the oldest metropolitans at which several traditional trades and crafts, such as pottery and leather, were established thousands of years ago **(10).**

Although work provides many economic and other benefits, a wide array of workplace hazards also present risks to the health and safety of people at work. These include chemicals, physical factors, biological agents, adverse ergonomic conditions, allergens, a complex network of safety risks, and a broad range of psychosocial risk factors **(11).**

It was found that work conditions in pottery clay area were rather dusty with much pollution from coal in the kilns and from clay used for pottery making. The greatest health risk is the potential to develop silicosis from the long-term exposure to crystalline silica **(5).**

Personal characteristics among studied population showed that among 185 workers examined in El-Fawakheer pottery area, male represented 97.8% of the studied population. Child and juvenile represented 10.2% of total workers in this study with mean ± SD of age 13.15 + 2.62, while the mean + SD of age of adult workers was 38.2 ± 14.5. Combined pottery and fiber glass was the commonest place of work where 86% of the studied group worked in that section.

Most of the studied workers were adult with mean ± SD of duration of exposure of 18.34 ± 13.56 while child mean ± SD duration of exposure was 4.16 ± 2.93. Mean ± SD of Work extent total hours was 49567.0 + 44406.5. **Hoy and Chambers. (12)** explained that the effect of work extent of silica exposure is assochiated with potentially fatal pneumoconiosis caused by exposure to respirable crystalline silica.

Child labor is very common in pottery industry despite that pottery industry is considered one of the most hazardous work places especially for children. Poverty is seen to be the major factor of child labor. This go with our study where in El-Fawakheer, child labor is markedly observed. This also agreed with **Lotfy et al., (10),** which stated that child labor is a challenging phenomenon in Egypt. Children in Egypt are engaged in child labor, including pottery, quarrying and domestic services. Basic environmental child risks are unhealthy housing, unsafe water supply, and lack of sanitation, indoor air pollution, and leaded gasoline. Emerging risks are, for example, endocrine disruptors, environmental allergens, and UV radiation **(13).**

The distribution of the population age in Egypt is such that a relatively high percentage of the population is young. Those below the age of 15 represent about 37.5% of the total population. Of this 37.5%, 7% of Egyptian children below the age of 15 were engaged in child labor in 2009. Egypt is the forth country with the highest percentage of child labor, according to the World Bank in 2015 **(14).**

Despite female workers represented only 2.2% in our study yet it's of rising major concern. According to **Kim et al., (15),** in modern society, the scale of the service industry which is more attractive for female workers, is continuously expanding. Therefore, this leads to increase numbers of working female.

The main route of exposure for respirable dust and fuel byproduct is inhalation. The lungs are target organ which are susceptible to different respiratory diseases **(16)**. This support our findings where workers were complaining from shortness of breath, cough and wheezes by (18.2, 10.8, 9.1%) respectively. This agreed with **Aziz et al., (17)** who explained the role of silica exposure and relation between respirable silica and different chest manifestation especially exertional dyspnea and cough

Fernández Álvarez et al., (18) stated that workers exposed to silica suffered from different systems complaints where chronic cough and exertional dyspnea were common findings**.** This agreed with the result of this study where more than half of the studied workers complained of chest, musculoskeletal, dermatological, GIT and nervous problems (38.3, 16.2, 10.2, 4.3, 3.7 % respectively). Also 55% had past medical history of diseases commonly diabetes, hypertension and asthma with prevalence of (19.4, 11.3 and 7 %) respectively. Several studies have shown direct relationship between various occupational related diseases especially chest manifestations and pottery work **(19).**

On auscultation Harsh vesicular breathing with prolonged expiration and rhonchi which occur in obstructive airway diseases like asthma and chronic bronchitis were predominately found among workers (17.2, 7%) respectively. This agreed with **Aziz et al., (17)** who stated that workers exposed to mineral dusts, are subjected to problems in the breathing efficiency because of silicosis and bronchitis.

Dermatological problem found in this study is supported by **Smith et al., (20)** who stated that irritant contact dermatitis is common in pottery industry because of the prolonged contact with water during clay preparation. Allergic contact dermatitis as results of additives found in the releasing agents have been reported.

Musculoskeletal complaints were the second most prevalent complain (16.2%) after chest problems. Chest bone deformities was frequently observed in chest x ray (8.6 %). The most frequently affected joints were knees and lower back (5.4 and 8.6%) respectively and on examination of the affected joint the most frequent signs among the workers were limitation of movement (9.7%). **Abdalla et al., (21),** explained that the poor environmental conditions and the lack of protective equipment in pottery workshops are key contributing factors in the development of many musculoskeletal disorders.

In this study, the distribution of irregular opacities were the most common reported radiological opacities followed by fibro-nodular then nodular opacities (14.1 %, 8.6% and 6.5%) respectively. This agreed with **Fernández Álvarez et al., (18)** who stated that radiographically, chronic simple silicosis revealed a profusion of small (<10 mm in diameter) opacities, typically rounded, and predominating in the upper lung zones. Also chronic exposure to dust of silica is associated with scarring of the lung in the form of nodular lesions in the upper lobes **(22).** However**, Oliver and Miracle, (23)** study's stated that despite participants exposed to silica for long period yet no opacities were found on chest X-ray.

Tuberculin skin test was positive in 4 workers out of the 185 studied workers. Two of them showed opacities (one nodular opacity and the other irregular opacity) in their chest x ray. This may be explained by **Lanzafame and Vento, (24)** who stated that diagnosis of active tuberculosis superimposed on silicosis is often problematic, especially in initial phases. The clinical spectrum of pulmonary tuberculosis is variable and the disease is accidentally discovered through a chest radiography **(25).**

Results also showed that five workers only had granulomas in their chest x ray (2.7%), those workers were tuberculin test negative. This is supported by **Baur et al., (26)** , who studied the effect of chronic exposure to dust loaded with silica in different industrial activities as pottery and ceramic, found a group of respiratory diseases characterized by the presence of pulmonary opacities in chest x-ray and these opacities may be of noninfectious granulomatous lung diseases.

Chest x-ray findings suggestive of asbestosis (pleural plaque) were found in 5 workers (2.7%), while pleural thickening was in 2.2%. According to **Rees and Murray, (27),** pleural plaques of asbestosis was found without clinical symptoms or signs. However, their presence means exposure to asbestos fibers with increased risk of development of mesothelioma**.**

In this study, irregular opacities were the most common reported radiological opacities among the different type of opacities (14.1 %). honeycombing is reported in (1.1%). This agreed with **Prazakova et al., (28)** who stated that according to the International Labor Office (ILO) criteria exposure to asbestos is associated with development of irregular reticulo-nodular opacities at the lung which coalesce with disease progression and become coarser with eventual honeycombing**. This is supported by Cullinan and Reid (29)** which stated that asbestosis is the commonest form of pneumoconiosis and pottery workers are among the risky group which need annual screening.

Results of this study showed that cardiomegaly was frequently observed in 7 %, this is the same with **Abdalla et al., (21)** study who explained respiratory outcomes associated with silica exposure. It included silicosis, chronic obstructive pulmonary disease (COPD) with cardiac complications, a fibrotic nodular disease of the lung parenchyma, pulmonary TB, lung cancer, and autoimmune diseases. The International Labor Organization (ILO) and the World Health Organization (WHO) have boarded a Global Elimination of Silicosis Campaign.

Regression analysis test between smoking and ventilatory function showed that smokers gave a lower value of FEV1% than 86.75% where partial correlation coefficient r of smokers = - 0.202 (with increased smoking there is decrease in the FEV1). This agreed with **Tantisuwat and Thaveeratitham, (30)** study who found decreased pulmonary function including forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC with smoking**.**

About one third (36%) of studied participants worked for less than 10 years. There is statistical significance different in FEV1% between child and Juvenile and adult. Regression analysis test showed that the older the worker the lower the values of FVC% and FEV1% than 86.3% and 86.75% respectively. Partial correlation coefficient r of age in years was found to be - 0.163 for FVC% and - 0.187 for FEV1%. This is similar with the postulation of **Ehrlich et al., (31)** which stated that pulmonary function test results may range between normal values and obstructive or restrictive patterns with marked decreases in FEV1 and FVC considering age and duration of exposure.

In this study, respirable Silica exposure levels in 5 samples out of 82 analyzed samples in different steps of pottery working, exceeded the accepted limit of the **Ministerial Decree 211 for the year 2003 "Limits of workplace pollutants" as promulgated by the Egyptian labour law number 12 for the year 2003**. While respirable dust exposure level exceeded the accepted limit in one sample out of 82 samples analyzed. Run time was significant in relation to different job description. Proper run time during environmental sampling plays a critical role in ensuring that obtained data is reliable and can be used as an estimate for the exposure.

Post hoc test was done and showed that the statistical significance was between screeping and shaping, molding and preparing kiln. This agreed with **Ramadan et al., (32)** which stated that respirable silica and dust are prevalent mainly in molding shaping and firing kiln among pottery crafts.

Regarding the environmental assessment, the concentrations of the suspended particulates (PM_{10}), at different workshops didn't exceed the accepted limit of the **Ministerial Decree 211 for the year 2003 "Limits of workplace pollutants" as promulgated by the Egyptian labour law number 12 for the year 2003**. Internationally, the recommended TLV for PM_{10} concentrations determined by the US Occupational Safety and Health Organization (OSHA) is 15 mg/m^3 **(33).**

The highest levels of measured particulates PM_{10} were observed in the workshops during feeding of oven. This may be attributed to the way of sampling by using (AerQuel Series 200 Newzealand) for PM10.

The environmental results of this study were in accordance with **Li et al., (34)** who stated that carbon emissions were crossing the limits prescribed by National Ambient Air Quality Standards in pottery industry. **Li et al., (35)** reported that type of fuel and incomplete combustion contribute to the release of contaminants in the environment. Most of the parameters of ambient air samples in **Li et al.** study exceeded the permissible standard. All of the criteria air pollutants (CO, SO2, NOx, $PM_{2.5}$, PM_{10}) except CO exceeded the National Ambient Air Quality Standard limit. Similar trends were also observed by **Shrestha and Raut, (36**). Carbon monoxide, the main byproduct of incomplete combustion of fuel is prevalent and accumulates primarily in the firing/loading sections included in the baking operation **(37).**

Prior to 2013, silica exposure in Egypt had been allowed to be up to 100 µg/m3 in pottery and ceramic workers and in construction workers even up to 250 µg/m3. Limit of exposure to crystalline silica is supplemented by ministerial decrees which elaborate more specific technical provisions, the most important ones being decree No. 211 (2003) specifying conditions and precautions essential for the provision of OSH measures at the workplace. It is important to indicate that the TLV list of the decree No. 211/2003 takes as a basis the ACGIH values of 2002, TLV (threshold limit value) for respirable silica (as α quartz) is 0.05 mg/m3 TWA for up to an 8-h / 6workday) **(38) and the National Institute of Occupational Safety and Health (NIOSH)** recommended exposure limit (REL) for respirable crystalline silica is 0.05 milligrams of respirable silica per cubic meter of air (mg/m3) as a time-weighted average (TWA) which is similar to the permissible limit of free silica according to the Egyptian labor law No. (12, 2003) **(39),** and now there are efforts from the authority to update it **(40).**

Conclusion

The present study showed that pottery craft workers are more prone for occupational exposure to respirable silica. Such exposure could lead to various health hazards including respiratory, musculoskeletal, skin, gastrointestinal and neurological disorders.

Occupational exposure to respirable silica carries risk for silicosis, increases risk for development of pulmonary TB, lung cancer and COPD among the exposed workers. Respirable silica is associated with pulmonary lung affection.

Further, environmental assessment of different pottery crafts showed increase in the threshold limit values according to the **Ministerial Decree 211 for the year 2003 "Limits of workplace pollutants" as promulgated by the Egyptian labour law number 12 for the year 2003** for both the respirable dust and respirable silica and different air pollutant (NOx and SOx).

It is important to mention that environmental sampling of different air pollutant (cox, NOx, sox and PM_{10}) need to be assessed by chemical method for sampling which wasn't available at our study, due to covid 19 pandemic and technical facilities.

Since silicosis is incurable, the management goals are to detect early cases of silicosis and TB through monitoring of both currently and formerly exposed workers; to establish surveillance programs; to slow progression; to prevent pulmonary TB infection and to reduce disability.

Recommendations

To reduce the respiratory adverse effects of industrial silica exposure among workers in pottery craft, it is important for the government, the owners of pottery workshops, the workers and the researchers to cooperate for better prevention and control of the occupational and environmental standards for pottery industry.

To the government

- Further advanced assessment of the pottery workers and detailed environmental sampling and analysis are highly recommended specially for silica and asbestos.
- Pottery crafts in Egypt are mostly owned privately and policy makers should impose and enforce stricter regulations to control silica dust exposure
- Registration and coverage of all pottery workers with health and social insurance umbrella.
- Stricter enforcement of the existing regulations by authorities.

To the owner

- Ensure pre-placement and periodic medical examination stressing the condition of the chest and skin.
- To reduce the adverse effects of industrial silica exposure, it is important to evaluate the degree, type, and source of exposure.
- Optimally, silica-containing materials should be replaced; work processes should be isolated and enclosed.
- Adequate ventilation and lighting should be provided; and ensure that workers used personal protective equipment at all times during possible silica exposure.
- Ensure training, PPE, regular health checkup, nutrition and hygiene for both the adults, juvenile and child working in pottery industry
- Ensure vaccination of workers against Covid-19 and seasonal flu

To the workers

- Workers should follow the instruction concerned with personnel protective equipment and occupational health and safety related to pottery industry.
- Workers should stop smoking and other bad habits that favors risk of pulmonary tuberculosis.
- Personal hygiene of the workers is highly recommended

To the researchers

- More researches for health and environmental impact of pottery industry and how to limit risk factors.
- More detailed environmental assessment.
- Regular training and participate in health campaign for under privileged pottery sector.

Limitations

- The overall sample is small compared to workers in pottery industry in Egypt.
- The sample was restricted to one region (El-Fawakheer area) only.
- Financial fund was limited to do further tests such as C.T. imaging for silicosis follow up and QuantiFERON Gold test for TB.

Limitations Due to covid 19 pandemic

- Not all workers accepted to participate in ventilatory function tests.
- Environmental sampling for air pollutant was done by spot device, while the best way of analysis is chemical analysis which wasn't available.
- Many workshops were afraid of the environmental assessment due restrictions from Ministry of Environment (only 4 workshops were allowed to operate the kilns per day.
- Female and most of child workers were afraid to participate in the study.

Conflicts of Interest: The authors declare no conflict of interest.

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