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Assessment of Lung Efficiency of Individuals Exposed to Various Foundry Industries in Satara City

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Abstract
The airborne dust as pollutants plays a major role in the overall atmospheric pollution. Silica is a chemical term for silicon dioxide (SiO2). The term crystalline silica refers to a crystallized form of SiO2 known as quartz, crystobalite or tridymite; it is the most abundant compound on the earth's crust capable of causing silicosis and lung cancer upon inhaling large doses in course of occupational exposure. The present study was aim to evaluate the lung efficiency of individuals who worked in various foundry industries in Satara city. Around 300 individuals were enrolled. From selected three locations, 100 individuals were enrolled. All the individuals from the test were given a pulmonary function test. Before the test, a questionnaire was given to them to collect their basic information. Their age, height and weight were also entered in the spirometer. The spirometer gives two values; one is the expected value and the other is actual value. The predicted values are based upon the age, height and weight of the person while the actual values are dependent upon the maximal inspiration and expiration of the person. All the parameters, i.e. FVC, SVC and MVV showed impairment in the large industry workers compared to other two industries workers. A significant difference ($p < 0.01$) in the actual and expected values was observed in the pulmonary function test individuals of all the three selected industries. The percentage efficiency for all parameters for small industry workers, i.e. FVC (96.42 %), SVC (95.71 %) and MVV (88.69 %) was also good as compared to large and medium industries. At large industry, MVV efficiency was very less (59.66 %) as compared to the medium industry (68.61 %) and small industry (88.69 %) workers. In the SVC also, a large industry worker (69.72 %) showed less value as compared to the medium industry (79.99 %) and small industry (95.71 %) workers. Restrictive defect was 14 %, 36 %, 33 % and 17 % in the large industry workers which was normal, mild, moderate and severe, respectively. These values were very low as compared to small industry workers. Individuals exposed to heavy load of pollutants in air are susceptible for many respiratory disorders. Decrease in the FVC, MVV and SVC parameters were observed in the individuals of large industry assz compared to medium and small industry. This impairment in the pulmonary test parameters are indications of an accumulation of pollutants in the airways, which intern reduces inhalation and exhalation force. So, the people

exposing continuously to such silica or particulate matter pollution should be made aware about pulmonary disorders.
Keywords: Pulmonary Function Testing, Forced Vital Capacity, Lung disorders, Foundry industries

1. Introduction

Air pollution is a major environmental health problem due to the industrial revolution in various developing and the developed countries (Simoni et al., 2015; Manisalidis et al., 2020; Kaur and Pandey, 2021). Silica is a chemical term for silicon dioxide (SiO2). The term crystalline silica refers to crystallized form of SiO2 known as quartz, crystobalite or tridymite; it is the most abundant compound on the earth's crust capable of causing silicosis and lung cancer upon inhaling large doses in course of occupational exposure (Zhang et al., 2010). In addition, silica can occur in noncrystalline forms, and several amorphous materials (Guthrie and Heaney, 1995; Laumbach and Kipen, 2012; Jiang et al., 2016). The increased air pollution due to developments specially industrialized countries which include growing cities, increasing traffic, various foundry industries, etc. (Chen and Kan, 2008).

A worker may develop one of three types of silicosis: chronic silicosis, accelerated silicosis and acute silicosis depending on the cumulative dose of respiratory crystalline silica (Altindag et al., 2003). Silicosis, usually a nodular pulmonary fibrosis, is a disease mostly associated with exposure to respiratory crystalline silica. Although, the reported mortality associated with silicosis has declined over the past several decades, 300 silicosis-associated deaths still occur each year in the US (Jafary et al., 2007; Azari et al., 2009). Foundry workers are potentially exposed to a number of carcinogens. Ahn et al. (2010) conducted a study to describe the cancer incidence associated with employment in small-sized Korea iron foundries and to compare those findings to the Korean population. The toxic chemicals and gases cause the irritation and allergy in the lungs (Pal et al., 2010). Air pollution exposure also triggers several cases of asthma, exacerbate (worsen) a previously-existing respiratory illness, and it leads to development chronic illnesses including lung cancer, emphysema and chronic obstructive pulmonary diseases (Kurt et al., 2016). For the manifestation of pathological condition, spirometry is a method through which measuring various lung volumes and airflow rates in and out of lungs (Chowdhury et al., 2008).

Hence, spirometer is used to assess pulmonary function effectively. As per literature survey, on primary care spirometry study by Derom et al., (2008) shown some important information on evaluation of respiratory symptoms to evaluate asthmatic condition. Baemani *et al.,* (2008) conducted a study to diagnose restrictive and obstructive abnormalities by using pulmonary parameters of Vital Capacity (VC), Forced Vital Capacity (FVC), Forced Expiratory Volume at 1st second (FEV1), the ratio of FEV1 to FVC (FEV1%), Peak Expiratory Flow (PEF) and Forced Expiratory Flow (FEF). Earlier study (Wagh et al., 2006) show that, influence of workplace on lung efficiency and found significant decline in FVC, PEFR and FEV1 as compared to the expected values which indicates the reduced lung efficiency due to exposure to dust. With this background, present study was aim to evaluate the lung efficiency of individuals who worked in various foundry industries in Satara city. In this study three tyes of indutrise *i.e.* small, medium and large foundary industries workers were assessed for their lung capacity.

2. Material and methodology

2.1 Study Area Selection

The study was carried out in industrial areas of the Satara city (Latitude 17.691401 and longitude 74.000938). Different study areas were selected based on production capacity of industries. The study industries were divided into three categorise i.e. large, medium and small industrise.

2.2 Enrollment of Individuals

In the present study, around 300 individuals were enrolled. From each selected industry 100 individuals were enrolled. Detailed present and past personal and occupational history were taken. Some parameters were included purposefully in the study, i.e. smoking history, frequency of smoking per day, and even if they have hard time during coughing, sneezing etc. This helped to determine the respiratory impairment, if any.

2.3 Assessment of Pulmonary Function Test

The primary instrument used in pulmonary function testing is the spirometer. It is designed to measure volume changes and can only measure the volume fractions of the lungs that exchange gas with the atmosphere. Spirometers (pneumotachs) with electronic signal outputs also measure flow (volume per unit time). Usually, the spirometer always has a device attached to it that measures the movement of gas in and out of the chest, called a spirograph. Changes in lung function can be investigated spirometrically and can be done quickly without harming the subject (Chattopadhyay, 1996). Factors such as age, gender, height, weight, geographical conditions, etc., particularly affect spirometric measurements when evaluating lung function.

All the individuals from the test were given a pulmonary function test. Before the test, a questionnaire was given to them to collect their basic information. Their age, height and weight were also entered in the spirometer. The spirometer gives two values; one is the expected value and the other is actual value. The predicted values are based upon the age, height and weight of the person while the actual values are dependent upon the maximal inspiration and expiration of the person. Sterilization of mouthpiece was done every time before use.

Severity of the pulmonary functions was determined as per Chowdhury et al., (2008). The range of severity was normal PFT (> 85 % of predicted values); mild disease (> 65 %, but < 85 % of predicted values); moderate disease (> 50 %, but < 65 % of predicted values) and severe disease (< 50 % of predicted values)

2.4 Statistical Analysis

All PFT were performed for 300 individuals. Results are represented as mean of five repeated test ± SD (Standard deviation). Significantly different from actual PFT values at $p<0.01$ by one way analysis of variance (ANNOVA). For statistical analysis, SPSS 14 software was used.

3. Results and Discussion

3.1 Respiratory Symptoms on Analysis of Questionnaire

Table 1 shows the Respiratory symptoms reported by the enrolled individuals, which was obtained by questionnaire method. Around 96 %, 22 % and 18 % from large, medium and small industries were faced hard time coughing and breathing at day time, respectively. Wheezing the chest was reported by 18 %, 10 % and 03 % from large, medium and small industries workers, respectively. Around 73 %, 16 % and 43 % from large, medium and small industrise workers were faced hard time while breathing due to dust, respectively. Hard time breathing due to smoke was reported by 28 % individuals by large industry, 13 % individuals of medium industry and 08 % individuals of small industry.

Hence, it shows that people of the large industry have comparatively intense respiratory problems as it is a highly polluted area than that of medium and small industries.

Table 1: Respiratory symptoms reported by the enrolled individuals

Sr. No.	Symptoms	Large industry	Medium industry	Small industry
1.	Hard time coughing or breathing at day time	96 %	22 %	18 %
2.	Chest wheezing during breathing	18 %	10 %	03 %
3.	Hard time breathing due to dust	73 %	16 %	43 %
4.	Hard time breathing due to smoke	28 %	13 %	08 %

3.2 Pulmonary Function Status

The study shows that values of FVC, SVC and MVV at large and medium industries workers are much lower than that of small industry workers (Table 2). All the parameters i.e. FVC, SVC and MVV showed impairment in the large industry workers compared to other two industries workers. A significant difference ($p < 0.01$) in the actual and expected values were observed in the pulmonary function test of individuals of all the three industrise.

Table 2. Pulmonary Function status of individuals at study industrise

Sr. No.	PFT	Large industry (n=100)		Medium industry (n=100)		Small industry (n=100)	
		Expected	**Actual**	**Expected**	**Actual**	**Expected**	**Actual**
1	FVC	3.81 ± 0.21	2.91 ± 0.85	3.16 ± 0.29	2.15 ± 0.41	3.01 ± 0.28	2.14 ± 0.11
2	SVC	4.21 ± 0.71	2.99 ± 0.53	4.01 ± 1.52	3.46 ± 0.35	3.81 ± 1.08	1.99± 0.47
3	MVV	92.41 ± 8.9	71.77 ± 5.2	97.01 ± 9.2	64.02±10.5	91.68 ± 7.5	61.92 ± 9.1

All PFT were performed for 300 individuals. Results are represented as mean of five repeated test ± SD (Standard deviation). Significantly different from actual PFT values at $p<0.01$ by one way analysis of variance (ANNOVA).

PFT: Pulmonary Function test; FVC: Forced Vital Capacity; MVV: Maximal Voluntary Ventilation; SVC: Slow Vital Capacity

Forced vital capacity is an important parameter for the spirometric study. The fall in FVC was observed at large industry workers which may be due to the accumulation of pollutants in the lungs and dust released in the airways, which reduces the force during inhalation and exhalation activity (Wagh et al., 2006). Maximal voluntary ventilation is the maximum amount of air breathed in or out of the lungs per minute and can be calculated (MVV= VC* Respiratory rate). Vital capacity (VC) is the maximum amount of air taken in or out of the lungs per breath. A person can increase his rate of respiration in case if oxygen requires more, as VC cannot be increased further (Pal et al., 2010). Chatterjee and Das (2013) have also concluded the deterioration in lung functions due to environmental pollution in Kolkata city.

Percent efficiency for PFT of the individuals is showed in the Table 3. The percentage efficiency for all parameters for small industry, *i.e.* FVC (96.42 %), SVC (95.71 %) and MVV (88.69 %) at small industry is also good as compared to large industry and medium industry. At large industry, MVV efficiency was very less (59.66 %) as compared to medium industry (68.61 %) and small industry (88.69 %). In the SVC also, a large industry (69.72 %) showed less value as compared to medium industry (79.99 %) and small industry (95.71 %).

Table 3. Percent Efficiency for PFT of the individuals

Sr. No.	PFT	Large industry	Medium industry	Small industry
1	FVC	62.81 %	79.35 %	96.42 %
2	SVC	69.72 %	79.99 %	95.71 %
3	MVV	59.66 %	68.61 %	88.69 %

All PFT were performed for 100 individuals. Results are represented as mean of five repeated test ± SD (Standard deviation). Significantly different from actual PFT values at $p<0.01$ by one way analysis of variance (ANNOVA).

PFT: Pulmonary Function test; FVC: Forced Vital Capacity; MVV: Maximal Voluntary Ventilation; SVC: Slow Vital Capacity

3.3 Ventilator Impairment Status

In small industry; about 69 %, 25 % and 06 % individuals showed normal, mild and moderate ventilator impairment status, respectively. Large industry showed about 33 %, 37 %, 21 % and 09 % individuals air flow obstruction like, normal, mild, moderate and severe, respectivevly. Restrictive defect was 14 %, 36 %, 33 % and 17 % in the large industry workers which was normal, mild, moderate and severe, respectivevly. These values were very low as compared to small factory workers. Table 4 shows ventilator impairment status of the individuals.

Table 4. Ventilator impairment status of the individuals

	Air Flow Obstruction			Restrictive Defect		
	Large industry	**Medium industry**	**Small industry**	**Large industry**	**Medium industry**	**Small industry**
Normal	17 %	33 %	69 %	14 %	39 %	54 %
Mild	45 %	37 %	25 %	36 %	42 %	18 %
Moderate	23 %	21 %	06 %	33 %	07 %	28 %
Severe	15 %	09 %	--	17 %	12 %	--

Jafary et al., (2007) have reported decrease in FVC, FEV1, FEF 25-75% of people exposed to roadside dust. Air pollution shows hazardous impacts on organ and systems of the human body. These effects can be ischemia, heart disease, cardiocerebral vascular disease, (Rückerl et al., 2006; Watson, 2006; Hassing et al., 2009; Scarborough et al., 2012; Gold and Samet, 2013); nervous system (Genc et al., 2012), digestive system (Kaplan et al., 2013), and urinary system (Castaño-Vinyals et al., 2008). Air pollution even has adverse effects on long-term ambient air pollution exposure was reported to increase all-cause mortality (Carey et al., 2013). Air pollution is the cause and aggravating factor of many respiratory diseases, like chronic obstructive pulmonary disease (COPD) (Kelly and Fussell, 2011; Faustini et al., 2013, Ana et al., 2014), asthma (Kelly and Fussell, 2011; Karakatsani et al., 2013), and lung cancer (Vineis et al., 2006; Benigno et al., 2010; Sax et al., 2013). Pal et al., (2010) have also reported the similar decrease in pulmonary parameters which also signifies restriction to the lung expansion, obstruction and narrowing of the airways in traffic police personnel compared to the general police personnel.

4. Conclusions

Individuals exposed to heavy load of pollutants in the air are susceptible for many respiratory disorders. Decrease in the FVC, MVV and SVC parameters were observed in the individuals of region 1 as compared to regions II and III. This impairment in the pulmonary test parameters are indications of an accumulation of pollutants in the airways, which intern reduces inhalation and exhalation force. Frequently pollution exposed individuals near highly polluted are i.e. Powai Naka showed pulmonary function impairment. So, the people exposing continuously to such vehicular pollution should be made aware about pulmonary disorders.

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5. References

[1]Ana GR, Odeshi TA, Sridhar MK, Ige MO. Outdoor respirable particulate matter and the lung function status of residents of selected communities in Ibadan, Nigeria. Perspect Public Health. 2014;134(3):169-175.
[2]Kurt OK, Zhang J, Pinkerton KE. Pulmonary health effects of air pollution. Curr Opin Pulm Med. 2016; 22(2):138-43.
[3]Jiang XQ, Mei XD, Feng D. Air pollution and chronic airway diseases: what should people know and do? J Thorac Dis. 2016; 8(1):E31-40.
[4]Laumbach RJ, Kipen HM. Respiratory health effects of air pollution: update on biomass smoke and traffic pollution. J Allergy Clin Immunol. 2012; 129(1):3-11; quiz 12-3.
[5]Simoni M, Baldacci S, Maio S, Cerrai S, Sarno G, Viegi G. Adverse effects of outdoor pollution in the elderly. J Thorac Dis. 2015;7(1):34-45.
[6]Kaur R, Pandey P. (2021) Air Pollution, Climate Change, and Human Health in Indian Cities: A Brief Review. Front. Sustain. Cities, Sec. Climate Change and Cities Volume 3 - 2021
[7]Chen B, Kan H. Air pollution and population health: a global challenge. Environ Health Prev Med. 2008; 13(2):94-101.
[8]Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E. (2020) Environmental and Health Impacts of Air Pollution: A Review. Front. Public Health, Sec. Environmental health and Exposome, Volume 8 – 2020

[9]Ana GR, Odeshi TA, Sridhar MK, Ige MO. Outdoor respirable particulate matter and the lung function status of residents of selected communities in Ibadan, Nigeria. Perspect Public Health. 2014 May;134(3):169-75. doi: 10.1177/1757913913494152. Epub 2013 Aug 1. PMID: 23907630.

[10] Faustini A, Stafoggia M, Colais P, et al. Air pollution and multiple acute respiratory outcomes. Eur Respir J 2013;42:304-13.

[11] Kelly FJ, Fussell JC. Air pollution and airway disease. Clin Exp Allergy 2011;41:1059-71.

[12] Karakatsani A, Analitis A, Perifanou D, et al. Particulate matter air pollution and respiratory symptoms in individuals having either asthma or chronic obstructive pulmonary disease: a European multicentre panel study. Environ Health 2012;11:75.

[13] Vineis P, Hoek G, Krzyzanowski M, et al. Air pollution and risk of lung cancer in a prospective study in Europe. Int J Cancer 2006;119:169-74.

[14] Sax SN, Zu K, Goodman JE. Air pollution and lung cancer in Europe. Lancet Oncol 2013;14:e439-40.

[15] Watson KE. Air pollution and heart disease. Rev Cardiovasc Med 2006;7:44.

[16] Scarborough P, Allender S, Rayner M, et al. Contribution of climate and air pollution to variation in coronary heart disease mortality rates in England. PLoS One 2012;7:e32787.

[17] Rückerl R, Ibald-Mulli A, Koenig W, et al. Air pollution and markers of inflammation and coagulation in patients with coronary heart disease. Am J Respir Crit Care Med 2006;173:432-41.

[18] Hassing C, Twickler M, Brunekreef B, et al. Particulate air pollution, coronary heart disease and individual risk assessment: a general overview. Eur J Cardiovasc Prev Rehabil 2009;16:10-5.

[19] Gold DR, Samet JM. Air pollution, climate, and heart disease. Circulation 2013;128:e411-4.

[20] Genc S, Zadeoglulari Z, Fuss SH, et al. The adverse effects of air pollution on the nervous system. J Toxicol 2012;2012:782462.

[21] Kaplan GG, Tanyingoh D, Dixon E, et al. Ambient ozone concentrations and the risk of perforated and nonperforated appendicitis: a multicity case-crossover study. Environ Health Perspect 2013;121:939-43.

[22] Castaño-Vinyals G, Cantor KP, Malats N, et al. Air pollution and risk of urinary bladder cancer in a case-control study in Spain. Occup Environ Med 2008;65:56-60.

[23] Carey IM, Atkinson RW, Kent AJ, et al. Mortality associations with long-term exposure to outdoor air pollution in a national English cohort. Am J Respir Crit Care Med 2013;187:1226-33.

[24] Baemani M.J., Monadjemi A. and Moallem P., (2008), Detection of Respiratory Abnormalities Using Artificial Neural Networks, Journal of Computer Science, Vol. 4(8), pp: 663-667.

The Ciência & Engenharia - Science & Engineering Journal
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[25] Benigno Linares B., Guizar J. M., Amador N., Garcia A., Miranda V., Perez J. R. and Chapela R. (2010), Impact of air pollution on pulmonary function and respiratory symptoms in children, BMC Pulmonary Medicine, Vol. 10(62), pp: 1-9.

[26] Pinaki Chatterjee1 and Paulomi Das, Changes in Lung Function status of Adult Female over last one decade: A Cross-Sectional study in Kolkata, India, International Research Journal of Environment Sciences Vol. 2(7), pp: 30-34,

[27] Chowdhury S.R., Chakrabarti D. and Saha H., (2008), Development Of An Fpga Based Smart Diagnostic System For Spirometric Data Processing Applications, International Journal On Smart Sensing And Intelligent Systems, Vol. 1(4),pp: 985-1018.

[28] Derom E., Weel C., Liistro G., Buffels J., Schermer T., Lammerse E., Wouters E. and Decrame M.,(2008), Review: Primary care spirometry, Eur Respir J, Vol 31, pp: 197–203

[29] Hanif M., Sadiq H., Tayaba A. and Naz I,(1992), Determination of lead in human blood due to automobile exhaust, Science International, Vol. 4(3), pp: 265-267.

[30] Ingale S.T. and Wagh N., Impact Of Highway Traffic Pollution On Lung Function Of Residential Pollution In Jalgaon Urban Center, Advanced OR And AI Methods In Transportation.

[31] Ingale S. T., Wagh N. D., Pachpande B. G., Patel V. S., (2005), The influence of workplace environment on lung function of shopkeeper working near National highway in Jalgoan : A note. Transportation Research Part- D, 10, pp: 476-482.

[32] Jafary Z. A., Faridi I. A., Qureshi H. J. (2007), Effects Of Airborne Dust On Lung Function Of The Exposed Subjects, Pak J Physiol, Vol. 3(1), pp: 30-34.

[33] Pal P., Robert J. A., Dutta T. K. and Pal G. K., (2010), Pulmonary Function Test In Traffic Police Personnel In Pondicherry, Indian J Physiol Pharmacol, Vol. 54(4), pp:329–336.

[34] Wagh N. D., Pachpande B.G., Patel V.S., Attarde S.B. and Ingale S.T. (2006), The Influence of Workplace Environmenat on Lung Function of Flour Mill workers at Jalgaon Urban Centre, Journal of Occupational Health, Vol. 48, pp:396-401.

[35] Guthrie GD, Heaney PJ (1995). Mineralogical char-acteristics of silica polymorphs in relation to their biological activities. Scand J Work Environ Health, 21 (Suppl 2), 5- 8.

[36] Zhang M, Zheng YD, Du XY, Lu Y, Li WJ, Qi C, et al. Silicosis in automobile foundry workers: a 29-year cohort study. Biomed Environ Sci 2010; 23(2):121-9.

[37] Altindag ZZ, Baydar T, Isimer A, Sahin G. Neopterin as a new biomarker for the evaluation of occupational exposure to silica. Int Arch Occup Environ Health 2003;76(4):318-22.

[38] Azari MR, Rokni M, Salehpour S, Mehrabi Y, Jafari MJ, Moaddeli AN, et al. Risk assessment of workers exposed to crystalline silica aerosols in the east zone of Tehran. Tanaffos 2009; 8(3): 43-50.

[39] Ahn YS, Won JU, Park RM. Cancer morbidity of foundry workers in Korea. J Korean Med Sci 2010;25(12):1733-41.