

Assessment of Impact of High Particulate Concentration on Peak Expiratory Flow Rate of Lungs of Sand Stone Quarry Workers

Suresh Kumar Singh^{1*}, G. R. Chowdhary¹, and Gopal Purohit²

¹Department of Civil Engineering, Faculty of Engineering, J.N.V. University Jodhpur (Rajasthan), India 342011

²Department of Respiratory Diseases & Tuberculosis, Dr. S. N. Medical College, Jodhpur, India 342011

*Correspondence to: Dr. Suresh Singh, Email: sksingh_jnvu@yahoo.co.in

Received: 21 June 2005 / Accepted: 31 January 2006 / Published: 31 December 2006

Abstract: This study was designed to assess the impact of high particulate concentration on peak expiratory flow rate of lungs of sand stone quarry workers. The workers were engaged in different types of activities such as drilling, loading and dressing. These different working conditions had different concentrations of RSPM, leading to different exposure levels in workers. It was found that exposure duration and exposure concentrations were the main factors responsible for damage to the respiratory tracts of the workers. The particles were deposited at various areas of the respiratory system and reduced the peak flow rate. It was also revealed from the study that most of the workers suffered from silicosis if the exposure duration was more than 20 years.

Keywords: Peak expiratory flow rate (PEFR), respirable suspended particulate matter (RSPM), silicosis, respiratory tract

Introduction

The mining of various minerals and materials is going on since the man has thought about the development. In ancient age mining was done by the manpower and machinery involvement was negligible. Invention of new tools has increased mining activities but at the same time the pollution level also increased. The increase in the pollution level increases the chances of occupational diseases. The type of occupational diseases depends upon the type of pollutant. The consequence, of an inhaled particle depends on its inherent toxicity, its ability to penetrate the site at which it can exert its effects and the amount retained in the lung [6]. The toxicity of the particles retained in the lungs depends upon the chemical composition of the particles [2]. The sand stone quarrying has been established as the largest industry of Jodhpur (India). The quarrying of sand stone around Jodhpur has been going on prior to its inhabitation in the year 1459 AD [4]. More than hundred thousands workers are employed for quarrying and its related activities. Jodhpur sand stone rests uncomfortably over a highly rugged basement of Malani Rhyolite and has been assigned Cambrian Age. Structurally Jodhpur rocks are undeformed, lithofacies and

are almost horizontal which helps towards easy quarrying [5]. The working capacity of workers starts decreasing with the increase of working duration in quarries. This decrease in working capacity is because of the damages in the respiratory tract due to deposition of RSPM. PEFR relates to obstruction of larger airways, if diagnosed earlier then preventive measure can be taken, before development of serious respiratory problems hence this parameter was taken for study. This study relates the reduction in PEFR due to exposure duration and RSPM concentration.

Observations

A comprehensive methodology was adopted for taking the observations. The various steps undertaken are:

1. Stone quarries were selected to cover all the deposits around Jodhpur.
2. Selection of workers: Selection of workers was based upon the exposure duration, type of works and socioeconomic factors. Persons having any respiratory problem were excluded from the study. Only male workers were considered because female workers percentage is negligible.

3. Development of questionnaire: The ATS-DLD (American Thoracic Society- Division of Lung Diseases) questionnaire was modified and prepared in 'Hindi' language
4. Respirable Particulate concentration in ambient air was measured with the help of 'High Volume Air Sampler' for every activity. These activities are designated as loading, dressing and drilling and the workers who perform these works are called labour, dresser and driller respectively. The concentrations of these activities are designated as 1, 2 and 3 for normal quarry environment (i.e. loading), dressing and drilling respectively.
5. The Peak expiratory flow rate (Maximum expiratory flow rate that can be achieved and sustained for a period of 1.0 sec) of workers engaged in different type of activities was measured with the help of Spirometer (Spiroweb, manufacture by drcdrecare, Hyderabad, India). The predicted value of Peak Expiratory Flow Rate (PEFRp- it depends upon height, weight and age of human) of each worker was calculated by using ERS -93 Equations. Table- 1 gives the average value of RSPM.

Table 1: Particulate concentrations for different activities

Activity	Particulate concentration	Concentration category
Normal Quarry Environment	4800 µg/m ³	1
Dressing	9300 µg/m ³	2
Drilling	18500 µg/m ³	3

Table 2: Category of workers and exposure duration

Category of workers	Exposure duration in Years	Number of workers	Exposure category
Labour (132)	0-5	26	1
	5-10	31	2
	10-15	29	3
	>15	46	4
Dresser (126)	0-5	27	1
	5-10	33	2
	10-15	31	3
	>15	35	4
Driller (116)	0-5	26	1
	5-10	33	2
	10-15	28	3
	>15	29	4
Control workers	-----	45	-----

The control population was selected from the society of same socioeconomic status but these workers were not exposed to mine environment but they are exposed to normal ambient environment. The effect on respiratory tract is chronic therefore exposure duration was divided in four categories, 0-5 yr., 5-10 yr., 10-15 yr. and >15 yr. and these categories are designated as 1, 2, 3 and 4 respectively. Categories of workers, number of workers in each categories and exposure categories are given in table- 2.

The reduction in Peak Expiratory Flow Rate of lung is calculated and it is designated as IPEFR and is given by Eq-1. The values of PEFRp are calculated by ERS-93 Equation[7] (i.e Eq 2 & Eq 3). The mean values of index (IPEFR) are shown in table- 3. The PEFR and other required parameters (i.e. height, weight, age and sex) of 419 workers were recorded out of which 374 were quarry workers and 45 were in the category of control population.

Table 3: Mean values of index

No .of workers	Worker Category	EXP DUR	EXCAT	PCAT	Mean IPEFR
26	Labour	0-5	1	1	0.4355
31	Labour	5-10	2	1	0.4800
29	Labour	10-15	3	1	0.4727
46	Labour	>15	4	1	0.5669
27	Dresser	0-5	1	2	0.4593
33	Dresser	5-10	2	2	0.5166
31	Dresser	10-15	3	2	0.5685
35	Dresser	>15	4	2	0.6078
26	Driller	0-5	1	3	0.5329
33	Driller	5-10	2	3	0.5798
28	Driller	10-15	3	3	0.6220
29	Driller	>15	4	3	0.6568
45	Control Population	---	---	---	0.3209

$$\text{IPEFR} = (\text{IPEFRp} - \text{PEFR}) / \text{PEFRp} \dots\dots\dots(1)$$

(A) Males (>18 years):

$$\text{PEFRp} = 0.0614 \times H - 0.043 \times A + 0.15 \dots\dots\dots(2)$$

(B) Males (<18 years):

$$\text{PEFRp} = 0.0806 \times H - 6.9865 \dots\dots\dots(3)$$

6. **Morbidity Analysis:** ATS-DLD questionnaire was used for study. The different types of respiratory problems found among the workers are given in table 4. The results are shown in terms of percentage of population suffering from different types of problems.

Table 4: Prevalence of combination of different respiratory problems in quarry workers

Type of respiratory problem in combination	Prevalence in percentage
Wheezing	3.8
Cough	7.5
Dyspnoea	10.9
Silicosis	2.4
Tuberculosis	0.3
Wheezing, Dyspnoea	3.5
Dyspnoea, Silicosis	3.5
Cough, Wheezing	1.6
Dyspnoea, Cough	1.2
Wheezing , Dyspnoea, Cough, Silicosis	5.6
Dyspnoea, Silicosis, Asthma	5.3
Dyspnoea, Cough, Silicosis	3.5
Wheezing , Dyspnoea, Cough	4.1
Wheezing , Dyspnoea, Cough, Silicosis, Asthma	1.9
Wheezing , Dyspnoea, Cough, Silicosis, Tuberculosis	1.1
Wheezing , Dyspnoea, Cough, Silicosis, Asthma, Tuberculosis	1.3
Other combination of problems	1.1
Population with “No Problems”	41.4

Regression Analysis for IPEFR

The mean values of index IPEFR are calculated for various cases and are shown in table 3. A multiple linear regression model with dependent variable Y and independent variables X_1 and X_2 is considered:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \dots\dots\dots(4)$$

Where, β_0 , β_1 and β_2 are constants and are known as the parameters of the model. The dependent variable IPEFR is denoted by ‘Y’. The independent variables EXCAT (i.e. exposure categories of workers) and PCAT (i.e. particulate concentration categories) are denoted by X_1 & X_2 respectively. The regression analysis is done by using the data from table- 3. Let the estimates of β_0 , β_1 and β_2 are denoted by b_0 , b_1 and b_2 respectively. The values of b_0 , b_1 and b_2 are obtained by the principle of least squares. The data given in table -3 are analyzed and calculated statistical parameters are given in table 5.

Table 5: Values of Statistical parameters

Statistical Parameter	Values
R	0.976
R –Square	0.953
F	90.296
b_0	0.326, (t=19.267)
b_1	0.04153, (t=9.515)
b_2	0.05673, (t=9.490)
Std. error of the estimate	0.0169062

Analysis of Variance for Regression

$$H_0: \beta_1 = \beta_2 = 0 \text{ against } H_1: \text{not all } \beta_k = 0: (k=1, 2)$$

From table-5 the value of calculated ‘F’ i.e.

$$F = 90.296 \text{ and } F_{k, n-k-1, \alpha} = 8.02$$

Here $F > F_{k, n-k-1, \alpha}$; hence reject H_0 at α level of significance therefore significance of individual β 's be tested by ‘t – test’.

t-test (for Testing Individual β 's of Multiple Linear Regression Model)

$$H_0: \beta_j = 0 \text{ against } H_1: \beta_j \neq 0: (j=1, 2)$$

The calculated values for ‘t-statistics’ for β_1 and β_2 are given in table -5.

$$t \text{ (for } \beta_1) = 9.515$$

$$t \text{ (for } \beta_2) = 9.490$$

$$\text{The value of } t_{n-k-1; \alpha/2} = 2.26$$

Here $t > t_{n-k-1; \alpha/2}$; therefore reject H_0 . Hence $\beta_1 \neq 0$ and $\beta_2 \neq 0$

As the estimated b_0 , b_1 and b_2 are

$$b_0 = 0.326$$

$$b_1 = 0.04153$$

$$b_2 = 0.05673$$

The estimated multiple regression equation for IPEFR is:

$$Y = 0.326 + 0.04153 X_1 + 0.05673 X_2 \dots\dots\dots(5)$$

The value of R^2 is 0.953 which means that about 95 % of variation in the dependent variable “Y” (IPEFR) is due to independent variables X_1 and X_2

Significance Test for Mean IPEFR (For two Population Means)

To investigate the significance of the difference between the means of two normal populations viz. exposed and controlled for IPEFR; t-test and Cochran-cox test are applied. The t-test for two independent samples is applied when variances of both the populations (exposed and controlled) are unknown but equal whereas the Cochran-

cox test is applied for both the population, when the variances of both the populations are unknown and unequal. That is the choice between t-test and Cochran-cox test depends whether variances of both the populations are equal or not. Hence the equality of variances of both the populations can be tested by F-test (Variance Ratio Test).

For IPEFR the values of various test statistics: F, t, and Cochran-cox statistic, for different category of workers and controlled population are given in table 6. First F-test is applied for all the cases to test whether the variances of both the populations are equal. The value of F- statistics is given in col. (6) of the table. If the value of F-statistics is significant (such values are marked with *) the Cochran – cox test is applied and the value of test statistics t_c , for different cases are given in col. (13). Whereas, if value of F-statistic is insignificant then t-statistics for different cases, are calculated and its values are given in col. (9). Significant values of these statistics are marked with *. The critical values for F, and Cochran-cox tests are given in cols. (7) and (12). The critical value of 't' i.e.

$t_{n_1+n_2-2; \alpha}$ is taken as 1.96 (i.e. for normal distribution) [3].

It is observed from table-6 that the values of 't'-statistics or Cochran-cox test statistics, as the case may be are significant for all the cases. Thus it is concluded that there is significant difference between the mean indices for exposed & controlled populations for IPEFR.

Noting further that the mean values of concerning index for exposed population is considerably higher than the corresponding value of control population. Therefore, it indicates that Peak Expiratory Flow Rate of lungs of stone quarry workers are reduced due to the particulate pollution in quarries.

Conclusions

The study was carried out to find the effect of particulate concentration on peak expiratory flow rate of lungs of stone quarry workers. The results indicates that as the exposure duration increases the peak expiratory flow rate of lungs decreases and if exposure duration is same but concentration of particulate matter increases then again the peak expiratory flow rate of lungs decreases. Therefore the decrease in the peak expiratory flow rate of lungs depends upon the exposure duration and particulate concentration.

Table- 6: Tests for equality of means of exposed and control populations for IPEFR

Worker Category	Excat	n	MIPEFR	VRIMPEFR	F	$F_{v1, v2, 0.05}$	S_p	t	w_1	$t_{1\alpha/2}$	t_{cr}	t_c	TEST
Labour	1	26	0.4355	0.02781	2.593*	1.753	-----	-----	0.001112	2.0600	2.0518	5.57981	Cochran-Cox
Labour	2	31	0.4800	0.01788	1.657	1.720	0.01412	75.921*	-----	-----	-----	-----	t-test
Labour	3	29	0.4727	0.03842	3.565*	1.733	-----	-----	0.001372	2.0480	2.0429	6.03720	Cochran-Cox
Labour	4	46	0.5669	0.02485	2.280*	1.645	-----	-----	0.000552	2.0160	2.0157	11.92050	Cochran-Cox
Dresser	1	27	0.4593	0.02087	1.939*	1.747	-----	-----	0.000803	2.0560	2.0463	7.08343	Cochran-Cox
Dresser	2	33	0.5166	0.02537	2.349*	1.708	-----	-----	0.000793	2.0360	2.0310	8.89311	Cochran-Cox
Dresser	3	31	0.5685	0.01945	1.798*	1.720	-----	-----	0.000648	2.0420	2.0345	11.31670	Cochran-Cox
Dresser	4	35	0.6078	0.02483	2.295*	1.696	-----	-----	0.000730	2.0340	2.0292	12.08877	Cochran-Cox
Driller	1	26	0.5329	0.01235	1.149	1.753	0.01177	104.58*	-----	-----	-----	-----	t-test
Driller	2	33	0.5798	0.02001	1.845*	1.708	-----	-----	0.000625	2.0360	2.0300	11.84728	Cochran-Cox
Driller	3	28	0.6220	0.01930	1.795*	1.740	-----	-----	0.000715	2.0520	2.0425	12.64320	Cochran-Cox
Driller	4	29	0.6568	0.00892	1.205	1.798	0.01041	172.29*	-----	-----	-----	-----	t-test
Control Population		45	0.2297	0.01091	-----	-----	-----	$w_2=0.000248$		$t_{2\alpha/2}=2.0150$	-----	-----	-----

* Significant values of the test statistic under consideration.

**The critical value of 't' i.e. $t_{n_1+n_2-2; \alpha}$ is taken as 1.96 (i.e. for normal distribution)

The equation developed for the decrease in peak expiratory flow rate of lungs of stone quarry workers is given as eq-5 and the validity of the equation is tested statistically. The analysis indicates that decrease in peak expiratory flow rate of lungs of controlled and affected population has significant difference. This is because of working in the polluted atmosphere and this significant difference is statistically verified. It is revealed from this study that if the exposure duration is more than 15 years then the decrease in peak expiratory flow rate of lungs is 56% for labour, 60% for dresser and 65% for driller. The decrease in peak expiratory flow rate in such percentage leads to many respiratory problems like wheezing, cough, silicosis etc. It was found that 58.6% of workers are suffering from respiratory diseases.

References

1. Chatterjee, C. C.: "Human Physiology". *Medical Allied Agency, M. G. Road Calcutta-9*. **1987**.
2. Nemery, B.; Behr, J.; Bourke, S.; et. al: "Interstitial lung disease induced by exogenous agents: Factors governing Susceptibility." *Eur Respi Journal*, **2001**, 18(suppl-32):30-42.
3. Ostle, B.: "Statistics in Research". *The IOWA State College Press, AMES, IOWA*. **1954**.
4. Paliwal, B. S. (Ed): "Geological Evolution of Northwestern India.". *Scientific Publishers, Jodhpur, India*, **1999**.
5. Pareek, S.: "Basin configuration and sedimentary stratigraphy of Western Rajasthan." *Journal Geological Society of India*. **1981**. Vol-22: 517-527.
6. Parks, W. R.: "Occupational lung disorders 2nd Ed. *Butterworths & Co (Publishers) Ltd. London*, **1982**.
7. User Manual: "RMS Medspiror". *Recorders & Medicare Systems, 181/5 Phase-I, Industrial Area, Chandigarh India*, **1999**.

1. Chatterjee, C. C.: "Human Physiology". *Medical*