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Urban Air Pollution and Its Effect on Forced Expiratory Volume of Lungs

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ABSTRACT: *Air pollution in urban areas is due to different natural & man-made sources of pollution. Traffic is the main source of urban air pollution. Increasing vehicles are deteriorating the air quality of urban areas. The polluted air gets entry in the human body through inhalation. Various pollutants present in the ambient air damage the respiratory system and hence various pulmonary Function values are reduced. This reduction is evaluated in terms of Indexes. The objective of this study is to co-relate spirometric abnormalities with duration of exposure and Air Quality Index and to assess the reduction in lung capacity in terms of reduction of "Forced Expiratory Volume (FEV). The study was done at various locations of Jodhpur City, India. The study reveals that the 'Forced Expiratory Volume (FEV) of lungs decrease as the Exposure Duration and pollutants concentration increases. The estimated multiple regression equation for Reduction in Forced Expiratory Volume for 1second (FEV) (i.e. Index for FEV) is developed as*

$$Y_E = 0.047X_1 + 0.002X_2 - 0.066$$

The calculated values of 'y_E' give direct indication of damage severity without any medical or Pulmonary Function Test. The values y_F will be in between 0 to 1. If the value is more, this means the extent of damage is high.

KEY WORDS: *Lung capacity, Forced expiratory Volume for 1second (FEV)SO_2, NO_2, AQI, Multiple regression analysis, Pulmonary Function Test, ANOVA, Particulate Matter (PM)*

I. INTRODUCTION:

Urban air quality has a major impact on the physical & mental health of urban residents worldwide. Various air pollutants get entry in the human body through respiratory system. They damage the respiratory system and interfere with the natural metabolic and other activities of human body. Due to damage of respiratory system various "Pulmonary Function Values" are reduced. The present study is conducted at Jodhpur City to assess the reduction of Forced expiratory Volume for 1second (FEV) of residents due to ambient urban air pollution.

Jodhpur is the second largest city of Rajasthan and is situated in the western part of Rajasthan (India). The increased Army/Air Force, Industrial, Trade & Commerce and Tourism activities have led to expansion and growth of the city and other related economic activities up to a great extent. Although there are more than 100 pollutants/contaminants, which are broadly classified into two categories Particulate Matter and Gases. Here we are concerned with few important pollutants like Respirable Suspended Particulate Matter (PM_{10}), SO_2, and NO_2 only as vehicle pollution is the major source of pollution and most of the time ambient atmospheric condition remains unstable with moderate wind speed. Many environmental cum medical studies have been carried out worldwide to establish a link between different type of pollutants, respiratory diseases and level of pollution that would significantly affect human health. The acute health effect of suspended particulate matter (SPM), even at short term low levels exposure; include increased daily mortality and hospital admission rates for exacerbation of respiratory disease [5]. Long term exposure to $PM_{2.5}$ increases the risk of the non accidental mortality. Living

close to busy traffic appears to be associated with elevated risk [2]. The available human clinical results do not establish a mechanistic pathway leading to adverse health impacts for short term NO2 exposure at present day ambient environment [3]. In all the analytical studies total mortality was directly associated with long term exposure to particulate matter [4].Each day our lungs are directly exposed to more than 7000 liters of air, which contain varying amount of inorganic, organic particles and various types of gases. Hence it is required to assess the damage on the basis of air quality of the area. In this case study relationship between severity of the damage in terms of reduction in forced expiratory volume & exposure duration and concentration of pollutants (in terms of Air Quality Index) has been established.

II. METHODS AND METHODOLOGY OF CASE STUDY:

As per EPA guidelines concept of Air Quality Index (AQI) has been adopted. The AQI of different locations of Jodhpur has been determined to select the various spots for study. On these particular spots the most affected persons like traffic police, shopkeepers & their workers, watchman, hawkers etc. were selected for the study on the basis of their continuous exposure. The respiratory parameter considered in the study was Forced Expiratory Volume (FEV) and it was measured with the help of computerized Spirometer. Fine Particulate Sampler and High Volume Sampler were used in this study to measure the concentration of various pollutants considered in study. AQI was determined on the basis of concentration of pollutants.

2.1 Observations, Calculations and Analysis:

Concentrations of various pollutants (i.e. SO2, NO2 and PM10) were measured at selected locations of Jodhpur. Following four sites were selected as shown in table-1, for the measurements of concentration of various pollutants and for measurement of Forced expiratory Volume of exposed population.` Annual Mean values of pollutants measured at various sampling stations are given in table-1.From these concentrations of the pollutants, values of sub-indexes of respective pollutants were calculated to predict AQI. The formulae for sub-indexes calculation are depending on the range of concentration of respective pollutant and are given in table-2.

The highest value of sub-indexes for various pollutants for that sampling station is considered as AQI for that particular sampling station and is given in table-3.

Table 1: Annual Mean values of pollutants measured at various sampling stations

Sampling Stations No.	Location in Jodhpur	Parameters		
		SO_2 (µgm/m^3)	NO_2 (µgm/m^3)	PM_{10} (µgm/m^3)
1	Ratanada Bazar Circle	8.4	16.23	95.0
2	Akhliya Circle	11.87	18.16	115.0
3	Jalori Gate Circle	14.19	22.29	129.0
4	Nai Sarak – Sojati Gate Chauraha	21.19	24.66	143.0
Note- Periods of sand storms and rainy days were discarded.				

Table 2: Formulae used for sub-index calculation at different concentration of pollutant [1]

Pollutant	Concentration (X)	Formula
SO_2	$X < 40$	Sub-Index = 2.386363 X
	$X \geq 40$	Sub-Index = 1.6178737 (X-40) +100
NO_2	$X < 60$	Sub-Index = 1.666666 X
	$X \geq 60$	Sub-Index = 0.6220754 (X-60) +100
PM_{10}	$X \leq 50$	Sub-Index = X
	$50 < X \leq 150$	Sub-Index = 0.500000 (X-50) + 50
	$X > 150$	Sub-Index = 0.936768 (X-150) +100
Note: 1. Average concentration based on 24 hours (In ppb) 2. The formula for AQI for SPM has been used for calculating AQI for RSPM i.e. PM_{10}. The readings for SO_2 are calculated in µgm/ m^3. In above formula concentration of the pollutant are in ppb but we measure in µgm/ m^3 so that we convert this using Ideal Gas Law for SO_2 (1 µgm/m^3 = 0.381807252 ppb), for NO_2 (1 µgm/m^3 = 0.534413876 ppb).		

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Table 3: AQI value at different sampling station

Sampling Stations No.	Parameters and Sub-Index			AQI
	SO_2 (µgm/m^3)	NO_2 (µgm/m^3)	PM_{10} (µgm/m^3)	
1	7.66	14.46	72.5	72.5
2	10.82	16.17	82.5	82.5
3	12.93	19.86	89.5	89.5
4	19.31	21.96	96.5	96.5

After determination of AQI the exposed persons were selected for determining the reduction in FEV. The selection of persons was based on exposure duration (1 to 5 years of exposure, minimum exposure 8 hours or more each day). Persons having hereditary/ previous respiratory diseases, smoking habits, chewing of tobacco & alcoholic etc. were not taken for study. The control population was selected who were not exposed /little exposed to such environment but belongs to same socio- economic background for comparison purpose.

The actual value of FEV and predicted value of FEV was measured with the help of computerized spirometer for all the selected persons. Measured value is designated as FEV and predicted value is designated as FEV_P. The study subjects were divided in various categories depending upon their exposure duration

Index is developed to find out the extent of damage and percentage of volume reduction in fraction. This Index is designated as IFEV which is calculated with the help of following formulae:

$$IFEV = (FEV_P - FEV) / FEV_P \quad \text{----- (1)}$$

The Pulmonary function parameter FEV was measured for different persons for their different exposure duration at all sampling station. Numbers of observations for different exposure duration and for different AQI are given in Table-4 and Table-5. Mean values of IFEV (Index that represent reduction in Forced Expiratory Volume for 1.0 sec) was calculated for each case and is given in Table-4 and Table-5.

For the controlled population (population which was not exposed to urban pollution but belongs to same class of society) total 38 numbers of observations was taken and mean value of IFEV was calculated and its value was found 0.07

Table 4: Mean Values of IFEV for 1, 2, &3 years exposure

AQI	1 Yr. Exposure		2 Yr. Exposure		3 Yr. Exposure	
	No. of Obs.	Mean IFEV	No. of Obs.	Mean IFEV	No. of Obs.	Mean IFEV
72.5	27	0.1056	27	0.1181	28	0.1938
82.5	29	0.1095	29	0.1369	27	0.2320
89.5	27	0.1125	30	0.1453	28	0.2330
96.5	36	0.1435	34	0.1757	29	0.2340

Table 5: Mean Values of IFEV for 4 and 5 years exposure

AQI	4 Yr. Exposure		5 Yr. Exposure	
	No. of Obs.	Mean IFEV	No. of Obs.	Mean IFEV
72.5	26	0.2640	27	0.2710
82.5	28	0.2713	27	0.3090
89.5	35	0.2714	32	0.3180
96.5	28	0.2830	27	0.3289

Calculated and measured data shows the increasing trend for all the cases, which is not truly linear but most appropriate relation to represent this increasing trend is linear only. Regression analysis was done for IFEV and significance tests were applied to verify the consistency & significance of all the parameters of the multiple regression model. Various values of different parameters, coefficients and constants for developed model are given in table-6, table-7 and table-8.

Table- 6 Model summary

Model	R	R^2	Std. error of the Estimate
IFEV	0.943	0.889	0.02588

'R' is multiple co-relation coefficients. As the value of R is positive (from ANOVA Table) it is a positive co- relation. 'R^{2}' is coefficient of determination whose value is 0.889. It indicates that two independent variables Exposure Duration (EXDUR) and Air quality index (AQI) jointly account for the variation in IFEV up to 88.9% and remaining 11.1% variation is due to other reasons.

Table -7 ANOVA (Dependent Variable: IFEV)

IFEV	Sum of squares	df	Mean square	F
Regression	0.092	2	0.046	76.64
Residual	0.011	17	0.0006	
Total	0.103	19		

H_o: $\beta_1 = \beta_2 = 0$ & H_1: not all $\beta_k = 0$ (For k= 1, 2)

Where, d.f. is 'degree of freedom', and F is 'Ratio of Mean Squares'

ANOVA Table-7 gives the value of calculated value of $F_{calculated}$.(i.e. F=76.64) and critical value of F from standard tables (i.e. $F_{k, n-k-1, \alpha} = 3.59$).

Here, $F_{calculated} > F_{k, n-k-1, \alpha}$, Hence, reject H_0 at α (= 0.05) level of significance, therefore significance of individual β's be tested by't - test'.

Table -8 Coefficients (Predictors: (Constant), AQI, EXDUR)

IFEV	Coefficients		t
	b	Std. Error	
Constant	-0.066	0.057	-1.155
EXDUR	0.047	0.004	11.439
AQI	0.002	0.001	2.417

Where, Std. Error is 'Square root of ratio of Sum of Squares to Category of Samples' and t is 'ratio of Parameters difference (calculated value minus value from std. tables) to Standard error'.

H_0: $\beta_j = 0$ & 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-8.

t (for β_1) = 11.439
t (for β_2) = 2.417
The value of $t_{n-k-1, \alpha/2} = 2.11$
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 = (-) 0.066
b_1 = 0.047
b_2 = 0.002

Hence finally estimated multiple regression equation for IFEV that relate the extent of damage to the exposure duration and air quality index can be expressed as:

$$Y_E = 0.047X_1 + 0.002X_2 - 0.066$$

Where

Y_E = IFEV

X_1 = Exposure duration

X_2 = Air Quality Index

III. CONCLUSION:

The quality of ambient air in Jodhpur is worsening day by day due to increase of air pollutants concentration. Although the level AQI which is recorded as 'Moderate' (AQI < 100) but reduction in forced expiratory volume of lungs for exposure duration of 5 years is significant. Data indicated that as the Exposure Duration increases the percentage reduction in FEV of lungs increases. It also shows that the value of AQI index increases the reduction of forced Expiratory Volume of lungs increases. It is revealed from the study that exposure duration and deteriorated air quality both are responsible for reduction of FEV of lungs. The significant reduction in IFEV is due to air pollutants because the reduction is negligible in control population. It reflects that the 'Forced Expiratory Volume' of lungs decrease as the Exposure Duration increases as well as the pollutants concentration increases.

The estimated multiple regression equations directly gives relationship between decrease in FEV of lungs, exposure duration and air quality index.

$$Y_E = 0.047X_1 + 0.002X_2 - 0.066$$

. The values Y_E will be in between 0 to 1, if the value is more, this means the damage is high. Reduction in FEV indicates obstructive airways disease and diminished lung volume. It reveals that if residents are exposed to polluted ambient air, they may suffer from obstructive lung diseases which include; asthma, bronchitis and chronic obstructive pulmonary disease (COPD).

Hence from the developed equation, reduction in Forced Expiratory Volume of lungs can be calculated. The calculated values of 'Y_E' give direct indication of damage extent and will also help in identifying the respiratory diseases without any medical or Pulmonary Function Test.

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