Jr. of Industrial Pollution Control 23 (1)(2007) pp 189-195

STATISTICAL ANALYSIS OF INDOOR AIR POLLUTION PARAMETERS

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Key words : Respirable particulate matter, Multiple linear regression, ANOVA.

ABSTRACT

When we talk about air pollution in India and everybody thinks of the four metropolitan cities. But the ambient air quality in even smaller cities and towns is deteriorating alarmingly and in some cases much worse. Indoor air pollution is one risk that we can do something about. In the last several years, a growing body of scientific evidence has indicated that the air within homes and other buildings can be more seriously polluted than the outdoor air in even the largest and most industrialized cities. Other research indicates that people spend approximately 90 percent of their time indoors. Thus, for many people, the risks to health may be greater due to exposure to air pollution indoors than outdoors. Indoor pollution sources that release gases or particles into the air are the primary cause of indoor air quality problems in homes. Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the home. High temperature and humidity levels can also increase concentrations of some pollutants. If too little outdoor air enters a home, pollutants can accumulate Unless they are built with special mechanical means of ventilation, homes that are designed and constructed to minimize the amount of outdoor air that can leak into and out of the home may have higher pollutant levels than other homes. However, because

some weather conditions can drastically reduce the amount of outdoor air that enters a home, pollutants can build up even in homes that are normally considered leaky. A study of 100 kitchens was conducted in typical Indian kitchens at Jodhpur and Kota to assess the concentration of various air pollution parameters. The parameters were NO_x, SO_2, CO and particulate matter (SPM) and respirable particulate matter (RSPM). A regression analysis was then carried out between these parameters and volume of kitchen, opening area, and exhaust fan facility. It was concluded that the variation of the kitchen ~~parameters have significant effect on RSPM only.~~

INTRODUCTION

All of us face a variety of risks to our health as we go about our day-to-day lives. Driving in cars, flying in planes, engaging in recreational activities, and being exposed to environmental pollutants all pose varying degrees of risk. Some risks are simply unavoidable. Some we choose to accept because to do otherwise would restrict our ability to lead our lives the way we want. And some are risks we might decide to avoid if we had the opportunity to make informed choices. Indoor air pollution is one risk that we can do something about. In the last several years, a growing body of scientific evidence has indicated that the air within homes and other buildings can be more seriously polluted than the outdoor air in even the largest and most industrialized cities. Indoor pollution sources that release gases or particles into the air are the primary cause of indoor air quality problems in homes. Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the home. High temperature and humidity levels can also increase concentrations of some pollutants.

In addition, people who may be exposed to indoor air pollutants for the longest periods of time are often those most susceptible to the effects of indoor air pollution. Such groups include the young, the elderly, and the chronically ill, especially those suffering from respiratory or cardiovascular disease.

The housewives are working in an environment with cooking-generated pollutants such as NO_x, SO_2, CO and particulate matter (SPM) and respirable particulate matter (RSPM). So it becomes extremely essential to determine the causes and concentrations of possible gaseous pollutants, particulate matter, respirable particulate matter and their health effects.

MATERIAL AND METHODS

This study was conducted in typical Indian kitchens. In an Indian house, normally the combustion activity takes place in the kitchen only from where gaseous pollutants are generated. So, it was appropriate to monitor kitchen for possible gaseous pollutants, particulate matter and respirable particulate matter. For present study one hundred residences were chosen which had

different sizes of kitchen. Out of these 100 kitchens, 60 kitchens were selected in Kota and 40 kitchens were studied in Jodhpur. Further, these kitchens were selected on the basis of location of the houses. In Kota, 16 kitchens were selected in old city, 12 kitchens were studied around the outskirts of the city and remaining 32 kitchens were located in new city area. Similarly in Jodhpur, 10 kitchens were selected in old city, 9 kitchens were studied around the outskirts of the city and remaining 21 kitchens were located in new city area. The different sizes of kitchen were also indicative of the fact that they belonged to persons with different socio-economic status of living. The houses were also selected by considering their location.

To find out the variations and concentrations of indoor air pollutants in kitchen in the different seasons of a year, it was decided to monitor the indoor air quality in all the kitchens in every season. The year's duration is divided basically into three seasons namely winter (October, November, December, January); summer (February, March, April, May, June); rainy (July, August, September). RSPM was measured from the month of July to December.

STATISTICAL ANALYSIS (Multiple Linear Regression Model)

A multiple linear regression model with dependent variable Y and independent variables X_1, X_2 and X_3 is:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e \quad \text{......... (1)}$$

Where b_0, b_1, b_2 and b_3 are constants and known as the parameters of the model and the random variable (or error) $e \sim N(0, \sigma^2)$. In order to fit the above model, we need the estimates of the parameters β_0, β_1, β_2 and β_3 on the basis of a random sample of size 'n'.

For the i^{th} observation the model given in Eq. (1), gives

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + e_i \quad \text{......... (2)}$$

Let the estimates of β_0, β_1, β_2 and β_3 are denoted by β_0, β_1, β_2 and β_3 respectively. The values of $\beta_0 \beta_1 \beta_2$ and β_3 are obtained by the principle of least squares. The principle gives the estimates of β_0, $\beta_1 \beta_2$ and β_3 for which sum of the squares due to errors (SSE) is minimum.

$$SSE = \sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n} (y_i - \beta_0 - \beta_1 x_{1i} - \beta_2 x_{2i} - \beta_3 x_{3i})^2 \quad \text{......... (3)}$$

Thus the estimated multiple regression equation is given by:

$$\hat{y} = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 \quad \text{......... (4)}$$

Analysis of Variance for Regression

Analysis of variance helps to test whether each of the parameters b_1, b_2 and b_3 of the multiple regression model is 'zero'.

That is, to test

$H_0: \beta_1 = \beta_2 = \beta_3 = 0$ against H_1: not all $b_k = 0$ For $k = 1,2,3$

H_0 can be tested by F-Statistics under the following 'ANOVA' table set-up given in Table 1.

Table 1
ANOVA for multiple regression

Source of variation due to →	d. f.	SS	MS	F
Regression	*k*	SSR	MSR= SSR/*k*	(MSR/MSE)
Residual	*n*-*k*-1	SSE	MSE= SSE / (*n*-*k*-1)	
Total	*n*-1			

Note : For our study *k*=3

Where

$$SSR = R^2 \sum_{i=1}^{n} v_i^2$$

$$SSE = \left(1 - R^2\right) \sum_{i=1}^{n} v_i^2$$

$$R^2 = \frac{1}{\sum_{i=1}^{n} v_i^2} \left(b_1 \sum_{i=1}^{n} u_{1i} v_i + b_2 \sum_{i=1}^{n} u_{2i} v_i + b_3 \sum_{i=1}^{n} u_{3i} v_i \right)$$

$$v_i = y_i - \bar{y} \quad \text{and} \quad \bar{x}_j = \frac{1}{n} \sum_{i=1}^{n} x_{ji} \quad ; j = 1, 2, 3 \ \& \ i = 1, 2, \ldots n.$$

$$\bar{y} = \frac{1}{n} \sum_{i=1}^{n} y_i$$

$$u_{ji} = x_{ji} - x_j$$

'R' denotes the multiple correlation coefficient of y on x_1, x_2 & x_3. The R^2 is known as the coefficient of determination. The value of R^2 tells what part of the total variation in y is explained by x variables.

Decision Rule

The appropriate decision rule is that if calculated F ≤ $F_{k, n-k-1;}$ a do not reject H_0 and if calculated F > $F_{k, n-k-1;}$ a reject H_0 at a level of significance.

Note: In case the H_0 is rejected then the significance of individual b's be tested by the 't-test' described in the following sub-section.

't-test' for Testing Individual b**'s of Multiple Linear Regression Model**

Generally the problem before us is which of x'^s should be included in multiple linear regression model. This decision can be taken by testing the significance of β_1, β_2 and β_3 i.e.,
H_0 : β_j = 0 against H_1: β_j ¹ 0, j = 1,2,3

The test statistic under H_0 is

$$t = \frac{b_j}{s_{b_j}} \sim t_{n-k-1} \qquad \text{......... (5)}$$

Where, k =3 and β *j* (j = 1, 2, 3) is the estimated values of β*j* (j =1, 2, 3) respectively and is the standard error of β*j* and is given by

$$s_{b_j}^2 = \frac{\sum_{i}^{n} (y_i - \hat{y}_i)^2}{(n-k-1)} \left(\sum_{i=1}^{n} x_{ji}^2 - \left(\sum_{i=1}^{n} x_{ji} \right)^2 \Big/ n \right) \qquad \text{......... (6)}$$

Decision Rule

If calculated t <-t n-k-1, a/2 or t > t n-k-1, a/2 reject H0, otherwise H0 is not rejected.

Regression Analysis

Regression analysis is done and significance tests are applied to test the significance of all the parameters of the multiple regression models. The measured values of RSPM, volume of kitchen, opening area, and exhaust fan facility (if exhaust fan facility is in the kitchen then the value is assigned as "2" and if it is not then the value is "1") are prepared in tabular form.

The dependent variable KRSPM is denoted by 'y'. The independent variables KVOL (i.e. Volume of kitchen) and KOPN (i.e. opening area in the kitchen), KEXH (i.e. exhaust facility in the kitchen) are denoted by X1, X2 and X3 respectively. The regression analysis is done by using the data SPSS 9.0 (Software for statistical analysis). The analysed data are given in Table 2.

F-Test

H0: β1 = β2 = β3 =0 against H1 : not all bk = 0 : (k=1,2,3)

ANOVA table from Table 2 gives the value of calculated 'F' i.e.

F = 128.75 and Fk, n-k-1,α = 4.022 Where: α =0.05

Here F > Fk, n-k-1,α

Hence reject H0 at a level of significance, therefore significance of individual β'S be tested by 't - test'.

t-test

H0 : βj = 0 against H1: βj ¹ 0: (j=1,2,3)

The calculated values for 't'-statistic for β1 , β2 and β3 are given in Table 2-

t (for β1) = -13.224

t (for β2) = -2.598

t (for β3) = -9.604

The value of t n-k-1; a/2 = 1.988 (α =0.05)

Here t < -t n-k-1; a/2 ; therefore reject H0 . Hence β1 ¹ 0, β2 ¹ 0 and β3 ¹ 0

As the estimated β0, β1, β2 and β3 are

β0 = 228.497

Table 2
Regression analysis

Model

Mode	R	R
1	.895[a]	.801

a. Predictors: (Constant), EXH, VOL,

ANOV[b]

Mod		Sum Squar	df	Mea Squa	F
1	Regressi	52513.9	3	17504.6	128.7
	Resid	13051.6	96	135.9	
	Tot	65565.6	99		

b. Dependent Variable:

Coefficients[a]

Model		Unstandardized B	t
1	(Constant)	228.497	14.896
	VOL	-2.566	-13.224
	OPEN	-13.854	-2.598
	EXH	-27.372	-9.604

a. Dependent Variable: KRSPM

$\beta 1 = -2.566$
$\beta 2 = -13.854$
$\beta 3 = -27.372$

The estimated multiple regression equation for KRSPM is

$$Y = 228.497 - 2.566 X_1 - 13.854 X_2 - 27.372 X_3 \quad \ldots (7)$$

The value of R^2 is 0.801, which means that about 80% of variation in the dependent variable Y (KRSPM) is due to independent variables X_1, X_2 and X3.

The analysis was done by considering other parameters also like ambient temperature, humidity, wind velocity and wind direction but the effect of these parameters on RSPM were found insignificant, therefore they have not been considered in the model.

The dependency of CO, SO_2, NO_X and SPM on kitchen volume, opening in the kitchen was analysed but the effect of these pollutants was found insignificant. The reason being the low concentration of CO, SO_2 and NO_X and due to very little variation in concentration of SPM in the kitchens.

The equation can be used in the design of kitchen to maintain the pollutant level within the permissible limit.

RESULTS AND DISCUSSIONS

It was found that about 80% of variation in the concentration of respirable particulate matter in Indian kitchen is due to volume of kitchen, opening area in the kitchen and exhaust facility in the kitchen.

It was also concluded that parameters like ambient temperature, humidity, wind velocity and wind direction has insignificant effect on RSPM.

It was also found that the dependency of CO, SO_2, NO_X and SPM on kitchen volume, opening in the kitchen was insignificant.

ACKNOWLEDGEMENT

The author is thankful to his supervisors for providing kind guidance and all help during this study. He is also grateful to Principal and Head of the department of Civil Engineering, Engineering College, Kota and Head of the department of Civil Engineering, M.B.M. Engineering College, Jodhpur for permitting to use laboratory facilities as and when required.

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