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Estimation of number of deaths associated with exposure to excess ambient PM_{10} air pollution

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ABSTRACT: The respirable particle matter (PM_{10}) concentration in urban areas has been a chronic cause concern and principal reason for increased morbidity rate among resident population. The present study aimed at estimating a discrete event like mortality rate associated and attributable to excess particulate matter pollution in the Kathmandu Valley area. The Government of Nepal conducts air monitoring of particulates at its air monitoring site network covering valley area. Adopting the data available with respect to PM_{10} and with several other considerations like cutoff value for PM_{10}, mean annual concentration, demographic data of valley, exceedance to the reference cutoff value, attributable fraction evolution and computation relative risk attributable to PM_{10} was computed. Assumption was made about the relative risk of long-term average PM_{10} exposure on natural mortality estimated and reported from a previous study. The estimation or mortality rate in our case was 0.95% after all these considerations and computation. This implies that 95 deaths out of 10,000 deaths are due to particulate pollution existing in the Kathmandu Valley Area.

Key words: *Air pollution, PM_{10}, mortality, valley, Kathmandu*

INTRODUCTION

Particulates in an urban setting are emitted chiefly by human activities. The principal sources are fuel combustion, motor vehicle operation, industrial processes and open burning operations. The Suspended Particulate Matter (SPM) consists of finely divided small particulates with diameters of less than 10µg (PM_{10}) suspended in the medium of ambient air. This is one among the criteria air pollutant. It comprises among variety of substances, inorganic and organic carbon (containing polycyclic aromatic hydrocarbons), acidic or neutral sulphates and nitrates, fine soil dust, residues of lead and other toxic trace heavy metals, asbestos and other fibres. PM_{10} particles penetrate deep into the lungs and pose significant health risks (Folinsbee, 1992). The risks of adverse health effects are reported greater when particles enter the tracheo-bronchial and alveolar portions of the human respiratory system. PM_{10} is often associated with asthma and chronic cardiovascular and respiratory health problems. The PM_{10} induces acute respiratory morbidity (Pope, 1991). Thus ambient air monitoring of PM_{10} from air reflects respiratory morbidity (American Thoracic Society, 2000; Pierson, 1992) and hence considered an index of health.

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The chronic exposure to PM_{10} is associated with irreversible respiratory morbidity and even mortality. American Thoracic Society considered adverse health effects like detectable effects on clinical outcomes such as visits to the emergency department, hospital admissions, and mortality; symptoms related to air pollution associated with diminished quality of life or with a change in clinical status; any permanent loss of lung function; all reversible loss of lung function in combination with the presence of respiratory symptoms and decreased health-related quality of life as the adverse health effects of air pollution in its statement (Pope, 1991). The objective of the present study was to estimate the number of deaths associated with exposure to PM_{10} pollution considering relevant information available like annual mean concentration, exceedance observations to the reference values prescribed for PM_{10} and correlating with population exposed to the excess particulate pollution. This research have been done in Kathmandu, Nepal during June to December, 2006.

MATERIALS AND METHODS

The Government of Nepal has set up permanent air monitoring station network at six places and 24 h.

continuous air monitoring for PM_{10} is carried out. The levels of the PM_{10} is available in the website of the Government as a public domain and reference. The results of PM_{10} measurement conducted at six sampling sites, within the Kathmandu Valley area during the year June 2003 to May 2004 is considered for estimation of mortality attributable to the excess PM_{10} pollutant. Only those days were considered in which PM_{10} data were available in all six stations during the study period to get a better representation of PM_{10} concentration in the Kathmandu Valley. A set of 335 observations (N = 335) formed the database to the statistical analysis.

The Government of Nepal has categorized five different types of air quality categories based on levels of PM_{10}. The categories prescribed are range 0-60 µg/m^3 as "Good", 61-120µg/m^3 as "Moderate", 121-350 µg/m^3 as "Unhealthy", 351- 425 µg/m^3 as "Very Unhealthy", and >425µg/m^3 as "Hazardous". The same categories are maintained for the purposes of interpretation following statistical analysis. The number of occasions on which the particulate concentration values have exceeded these prescribed cut off points is considered as a measure of pollution level.

The Kathmandu Valley area comprises of Village Development Committees (9 wards form one VDC), one metropolitan, two sub-metropolitan areas and two municipalities. In fact, the six air monitoring sites represent all these areas. The nature of six monitoring sites represents valley background (One sampling site – Matsyagaon); urban road site (two sampling sites – Patan Hospital and Putalisadak); urban residential site (one sampling site – Thamel) and urban background site (two sampling sites – Bhaktapur and Tribhuvan University).

The official sampling stations of the Government of Nepal cover nature of the area in terms of predominant activities prevalent; however, the valley in general is a vast area and in all the areas the air sampling is not carried out. This fact necessitated to observe into the similarities and homogenous conditions associated with the areas directly under air monitoring network. This scrutiny led to group areas not directly falling under the set air monitoring sites to be included for the essential objective of estimating the mortality attributable to excess PM_{10} pollutant concentration. The geographical similarities, location uniformity in distance from core city areas, linkages to city core areas by an all season road, national highway passing through the area, areas associated with brick kilns, industrial sources of air pollution and the quality of air in terms of PM_{10} were the factors considered for including different wards of metropolitan, sub-metropolitan, municipalities and VDC's under the areas of six official air sampling sites. Such area was the composite area whose units aligned with the character and truly reflects the nature of official monitoring site. The inclusion was necessitated since PM_{10} data was available only with respect to the official six monitoring sites. The population officially published census data of 1991 and 2001 by Central Bureau of Statistics, Nepal was referred to estimate the mid year population of Kathmandu Valley in the year 2004 for which the PM_{10} concentration data is available. To project mid year population in 2004 geometric growth model was used. The Government of Nepal has prescribed that the quality of air is 'good' if the ambient PM_{10} concentration is within a reference value of 0- 60 µg/m^3. Therefore, an upper limit of 60 µg/m^3 was taken as a reference value for estimating exposure to ambient air pollution.

The following formula is considered to compute exposure to ambient air pollutants and subsequent estimation of number of deaths (mortality rate) attributable to excess PM_{10} pollution.

Exposure to ambient air pollutant

The necessary constituent parameters required to workout exposure to pollutant in the valley area were - Exposure to a pollutant, say *Y (*PM_{10} – in the present case) with reference value say RV_y (60 µg/m^3 for PM_{10} in the present case) along with the mean annual concentration CY_i in subpopulation Pi (of the *composite area*) and *P* (total valley population).

$$EX_y = \sum \left(\frac{P_i}{P} \right) * \left(CY_i - RV_Y \right)$$

Where, EX_y = Exposure to ambient air pollutants in total valley area. This gives population-weighted exceedance of reference concentration of PM_{10} in the valley. Value of this indicator shows that proportion of the population is exposed to harmful concentration level PM_{10}. Zero value means no population exposure above the reference value.

Estimation of number of deaths associated with PM_{10} (N_d)

To arrive at N_d the necessary parametrers are*:* EX_y (Exposure to ambient air pollutants in valley area – computed from above equation) and Attributable fraction in exposed (AF_E), Background mortality (B_M)

$N_d = AF_E * B_M$

Attributable fraction in exposed (AF_E), also known as attributable risk percent in the exposed

The attributable fraction in the exposed is the difference in the incidence of death (or other health related outcome) between people who are exposed to the risk factor and those who are not exposed, divided by the rate among those exposed. The computaion of AF_E could be done in two ways as shown below: Either by the formula,

$$AF_E = \frac{\text{(Incidence of death among those exposed) - (Incidence of death among those not exposed)}}{[\text{rate among those exposed}]}$$

Or alternatively it can be computed by direct use of relative risk, provided the relative risk is greater than one.

$$AF_E = \frac{\text{RR - 1}}{\text{RR}} \quad \text{provided that RR} > 1$$

In the present case the relative risk computation method was followed. A previous cohort study indicates that a relative risk of long–term average PM_{10} exposure on natural mortality was 1.1 per 10 μg/m^3 (WHO, 2000).

The relative risk 1.1 suggests that in an individual in a group exposed to long – term PM_{10} exposure is 1.1 times more likely to die than a individual in a group who is not exposed to long term PM_{10} exposure. Applying this analogy for the present case, in our study the attributable fraction exposed works out to be:

$$AF_E = \frac{\text{RR -1}}{\text{RR}} = \frac{1.1 - 1}{1.1} = 0.090909.... \approx 0.10$$

10% of the excess death that occurred among those exposed to long-term PM_{10} exposure was attributable to this exposure.

RESULTS

Descriptive statistics

The descriptive statistical analysis of PM_{10} values according to different monitoring stations observed during the study period (year June 2003 to May 2004) is presented in Fig. 1.

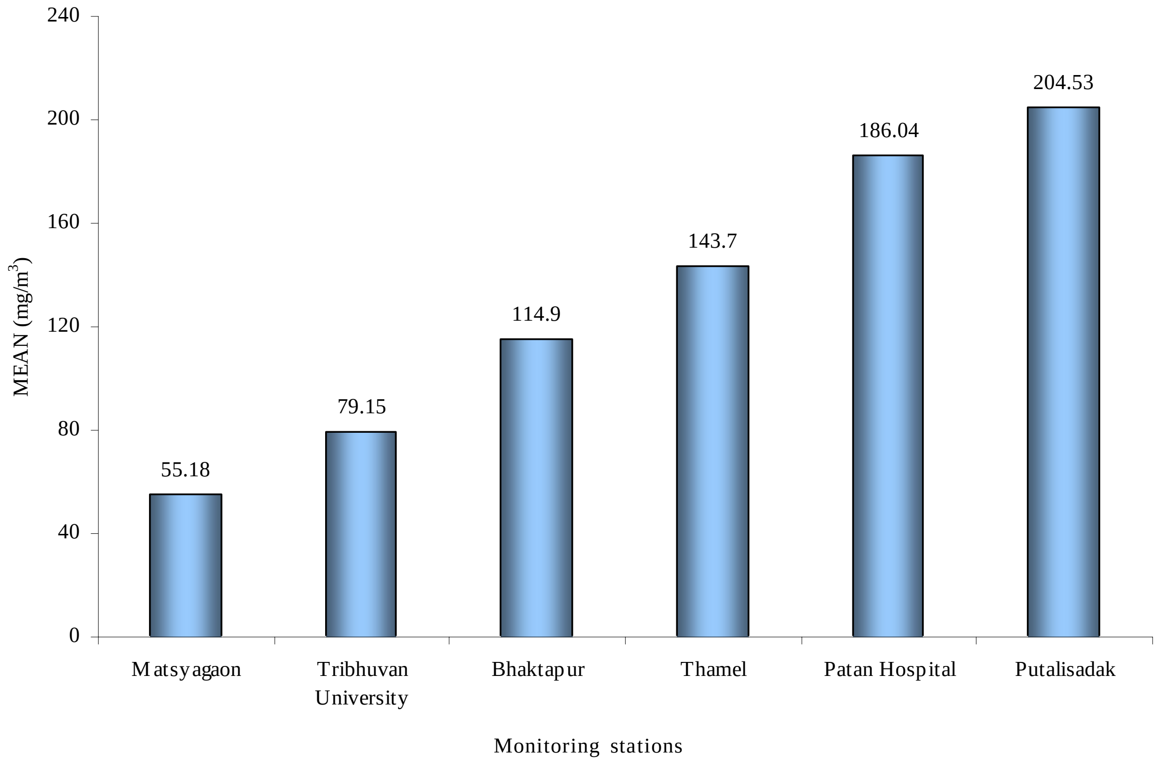

Fig. 1: Descriptive statistics of PM_{10} values (μg/m^3) in different air monitoring stations (N = 335)

The mean concentrations of PM_{10} observed reflect the characteristic of monitoring stations; there was wide variation within and between air monitoring sites including the overall valley concentration which ranged from 11g/m^3 to 474mg/m^3. The annual average concentrations in urban parts namely Thamel, Patan Hospital and Putalisadak were almost 2.6, 3.4, and 3.7 times higher than that observed in Matsyagaon.

Since 60 mg/m^3 is cutoff value considered for computation for excess PM_{10}, the Table 1 provides number of days in which PM_{10} exceedance was observed during the study period.

In Matsyagaon, most of the observations were less than 60 mg/m^3 where as in the other stations it exceeded. Wide variation existed with respect to particulate concentration as reflected by the number of days that the PM_{10} concentrations. The computational exercise and the results of individual calculations to arrive at population-weighted exceedance of PM_{10} in Kathamandu Valley are presented in the Table 2. The pre-requisite for this arrival was the calculation of mid year projected composite population for the year 2004 (column 2 of Table 2). Population-weighted exceedance of PM_{10} in Kathamandu Valley as computed from above table is 87.59282 mg/m^3

Estimation of number of deaths

The assumption was that the relative risk of long-term average PM_{10} exposure on natural mortality estimated from a cohort study is 1.10 per 10 mg/m^3 (95% CI = 1.03 – 1.18), (WHO, 2000). The exposure calculated in the present case leads to 87.59% of mortality due to all causes (except accidents) in Kathmandu Valley. The crude death rate in the year 2004 in Nepal as per Central Bureau of Statistics is 1080 per 100,000 (CBS, 2004). This death rate is used to estimate the number of deaths attributable to excess PM_{10} in the Kathmandu Valley. By using the formula for calculation number of deaths:

$$N_d = AF_E \times B_M$$

$$0.8759 \times 1080 \times 18.11 = 17132$$

Table 1: Number of days exceeding the PM_{10} episode thresholds

PM_{10} Levels (μg/m^3)	Matsyagaon	TU	Bhaktapur	Thamel	Patan Hospital	Putalisadak
<60	220 (65.7)	140 (41.8)	108 (32.2)	37 (11.0)	7 (2.1)	7 (2.1)
61 +	115 (34.3)	195 (58.2)	227 (67.8)	298 (89.0)	328 (97.9)	328 (97.9)
Total	335 (100.00)	335 (100.00)	335 (100.00)	335 (100.00)	335 (100.00)	335 (100.00)

Figures in brackets indicate the percentage

Table 2: Computation of exposure to ambient air pollutants

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
Air monitoring station	Mid year projected Composite population 2004 *(Pi)*	Ratio of i$^{th.}$ composite population to total valley population *(Pi/P)*	Mean annual concentration in i$^{th.}$ monitoring station *(CY_i)*	Reference value *(RV_y)*	Difference between Col. 4 & Col. 5 *(CY_i- RV_y)*	Population-weighted exceedance of PM_{10} in the i$^{th.}$ monitoring station *[(Pi/P) . (CY_i- RV_y)]*
Matsyagaon	182157 (Pi)	0.1005	55.18	60	-4.82	-0.48441
Tribhuvan University	327563	0.1808	79.15	60	19.15	3.46232
Bhaktapur	129775	0.0716	114.90	60	54.9	3.93084
Thamel	123698	0.0683	143.70	60	83.7	5.71671
Patan Hospital	851032	0.4698	186.04	60	126.04	59.213592
Putalisadak	197440	0.1090	204.53	60	144.53	15.75377
	1811665 (P) [Total valley population]					87.59282 [Population-weighted exceedance of PM_{10} in Kathamandu Valley]

This mortality figure stands at 17,132 deaths associated directly with PM_{10} pollution in the Kathmandu Valley area.

DISCUSSION AND CONCLUSION

A minimal average PM_{10} concentration in Matsyagaon area was noted. The Putalisadak area showed maximal PM_{10} concentration. This is an obvious finding since Matsyagaon is located far away from core areas of metropolis and principal reason to have monitoring over here was to reflect valley background level of air pollutant.

The results also show that the quality of air in Matsyagaon was under 'good' category. The quality of air in TU and Bhakatapur was under the 'moderate' category; the quality of air in Thamel, Patan Hospital and Putalisadak were under 'Unhealthy' category. Even on of the previous study also reports the total suspended particles (TSP) and PM_{10} values observed at different sample sites in the valley were higher than the WHO guideline values except in residential and control sites (Shah, 1997). Another study reports that in a typical metropolis, however, the vehicular traffic is a chief source of air pollution, particularly for particulate pollution. (Krishnamurthy, 1987). In the present case also excepting in Matsyagoan air monitoring station, higher exceedances of PM_{10} prevailed in all other stations.

Putalisadak, Patan Hospital and Thamel are in the core city area and have emerged as growing commercial centers of Kathmandu Valley. The traffic congestion is severe, vehicular movement is slow during peak daytime traffic hours. These areas could be potential sources of air pollutants for the entire valley area.

Kathmandu Valley is especially vulnerable to air pollution due to rapid and haphazard urbanization and significant increase of vehicular transport on narrow streets. Furthermore, the bowl like topography of the valley restricts wind movement and retains the pollutants in its atmosphere. This retention is pronounced in the winter season when climatic conditions are conducive for inversions and when cold air flows down from the mountains get trapped under a layer of warmer air, creating a lid, keeping the pollutants sealed within the valley area.

The total Kathmandu valley population is approximately 1.8 million. The death rate attributable to PM_{10} calculated taking the whole valley population is 0.95%. This means approximately 95 persons out of 10000 deaths are due to particulate pollution existing in the valley. This is estimate points out particulate pollution is among the key reasons for the mortality.

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