Health Impact of Particulate Pollution in Children: A Case Study of Kathmandu, Nepal

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Abstract

Introduction The relation between particulate pollution and respiratory morbidity is well established in other parts of the world. However there is dearth of such study in Nepal. This study aims to partially bridge this gap by serving as a baseline study in the study area.

Objectives The aim of the study was to investigate the reported effect of particulate pollution in the respiratory health of children in Kathmandu valley.

Methods Panel data related to PM^{10} concentration and ARI related hospitalization in the largest children's hospital in the study area was analyzed controlling for temperature, precipitation and relative humidity. For the analysis 29 month data was taken and Multiple (log-linear) Regression Model was used correcting for autocorrelation.

Results Descriptive analysis suggested that period having higher level of PM^{10} was coupled with period having higher inpatient cases related to ARI inside the valley. Similarly empirical analysis gave a positive and significant elasticity coefficient for PM^{10}.

Conclusions There seems a positive relation between PM^{10} level and ARI related hospitalization among children inside the valley. More precisely, a 1 percent point increase in PM^{10} level, *ceteris paribus,* results in about 0.544 percent point increase in the number of inpatient ARI cases (95% CI: 0.051488, 1.03683).

Key words Air pollution, Respiratory morbidity, Children, Nepal

Introduction

Air pollution measurements show that particulate pollution is the most significant pollutant inside the Kathmandu valley[1,2,3,4]. The main sources of particulate pollution in the valley are the brick industries, domestic fuel combustion, vehicle exhaust, re-suspension of the road dust and industrial boilers[5].

Particulate matter consists of a complex mixture of different organic and inorganic substances that are present in the air. The effect of particulate pollution in human health depends on the size and chemical composition of the particles. Particles of an aerodynamic diameter < 10 μg, referred as PM^{10}, are small enough to enter the human respiratory system. These respirable particles when inhaled are deposited in different regions of the respiratory system and may cause adverse health effects. Various research studies have shown that PM^{10} exposure has adverse health effects[6,7,8,9,10]. This type of air pollution has been closely linked to increase in respiratory morbidity (e.g. Acute Respiratory Infections, Chronic Obstructive Pulmonary Disease), aggravation of existing heart and lung conditions and even increased death rates. Studies have also shown that children are particularly vulnerable to such pollution, reason being greater respiratory rates, more time spent outdoors, immature immune system, to name a few.

Acute respiratory infections (ARI) in children less than five years old are the leading cause of childhood mortality in the world. World Health Organization (WHO) estimated that the annual number of ARI-related deaths in this age group (excluding those caused by measles and pertussis and neonatal deaths) was 2.1 million, accounting for about 20 percent of all childhood deaths[11]. In Nepal ARI is one of the major public health problems and is ranked as top three

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diseases affecting morbidity among children below 5 years of age[12]. The control of ARI is an important component of the child survival program in the Department of Health Services. On an average, children below 5 years of age in Nepal suffer 1.2 episodes of ARI a year[13].

Despite of the research studies concluding causal relation between particulate pollution and respiratory morbidity in children conducted in other parts of the world, there is need for such study in the Kathmandu valley. Conclusions on health impact of air pollution of other countries may be inappropriate and misleading because of the difference in the level of air pollution and its variants such as direction of wind flow, humidity, temperature, rainfall and variation in the vulnerable group that are exposed to it. Similarly there is dearth of prior study estimating dose-response relation between particulate pollution and adverse health effect in the study area. This study aims to partially bridge this gap in the study area.

The research study takes place in the Kathmandu valley which is especially vulnerable to air pollution due to its unique geographical and demographic characteristics. The study area has been experiencing an exploding population inflow, rapid urbanization, valley-centric industrialization and significant increase of vehicular transport in narrow streets in recent years.

Objective of the Study

The objective of the study is to investigate the health impact of Kathmandu's air pollution in children. To be specific, the study estimates dose-response relationship between particulate pollution and hospital admission related to acute respiratory morbidity in children

Methods

The reviewed literature suggested that air pollution has adverse effect on human health. ARI is the indicator of acute effect of air pollution in children. ARI, inter alias, depends upon pollutant concentration in the air. So we have taken morbidity count (number of ARI cases) as dependent variable and the level of PM^{10} as the independent variable in the model. Monthly levels of PM^{10} and hospital admissions for ARI related illness in the single largest public children hospital in the study area, Kanti Children's Hospital (KCH), has been related using 29 months data. The number of hospital admissions for ARI was obtained from the hospital records database. Ambient PM^{10} data was retrieved from the web page of Ministry of Population and Environment (MOPE)[14]. The PM^{10} concentration was averaged from the results monitored by six fix site stations in the valley (Putali sadak, Patan hospital, Bhaktapur, Kirtipur, Thamel and Matsyagaon). Since variables such as temperature, precipitation, relative humidity may control the variability of air pollution, their effect was statistically controlled in the analysis. Data of these meteorological variables (at Airport) were obtained from Department of Hydrology and Meteorology (DHM). Monthly averages of PM^{10} and meteorological variables (in BS) were computed for the study period using computer program *SM Date Converter* (provided by Computer Nepal). Magnitude of association has been estimated by Multiple Regression (Log-Linear) model using OLS procedure correcting for autocorrelation. Model of following specification was used in the study:

$$Y = A.\ PM_{10}^{\hat{a}1}.\ X_2^{\hat{a}2}.\ X_3^{\hat{a}3}.\ X_4^{\hat{a}4} \ldots\ldots\ldots\ldots (1)$$

Taking natural log on both sides,

$$\ln Y = \ln A + \hat{a}_1 \ln PM_{10} + \hat{a}_2 \ln X_2 + \hat{a}_3 \ln X_3 + \hat{a}_4 \ln X_4 \ldots\ldots\ldots\ldots (2)$$

or, $$\ln Y = \acute{a} + \hat{a}_1 \ln PM_{10} + \hat{a}_2 \ln X_2 + \hat{a}_3 \ln X_3 + \hat{a}_4 \ln X_4 \ldots\ldots\ldots\ldots (3)$$

Where,

Y = number of ARI patients hospitalized (the dependent variable)
A = constant
$\acute{a}$ = ln A
PM_{10} = PM_{10} level (explanatory variable)
$\hat{a}_1$ = coefficient of PM_{10}
X_2 = maximum recorded temperature, control variable (CV)
$\hat{a}_2$ = coefficient of X_2
X_3 = precipitation level (CV)
$\hat{a}_3$ = coefficient of X_3
X_4 = relative humidity (CV)
$\hat{a}_4$ = coefficient of X_4

From the above regression function, the mean values of dependent and independent variables were estimated and elasticity of the respective variable was estimated there from. The mean values of the variables are used for the elasticity estimation because the Population regression function (PRF) passes through the mean values of variables[15].

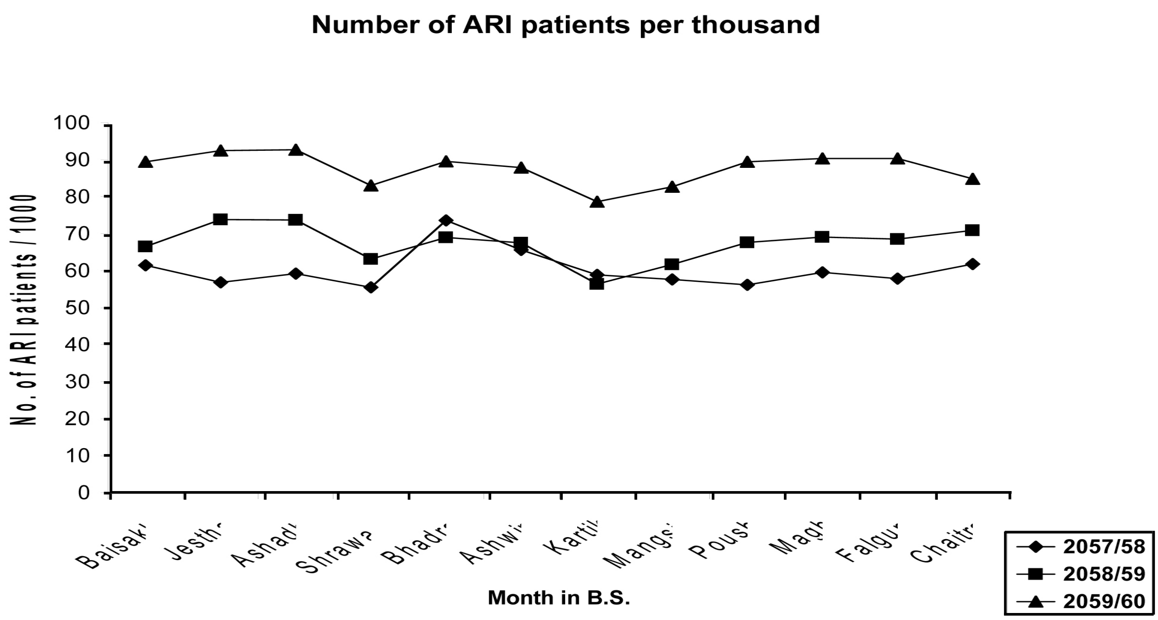
Similarly, descriptive analysis pertinent to incidence of ARI was also conducted. For this, hospital record data and data from Department of Health Services (DHS) [12] were used.

Results

Descriptive Analysis

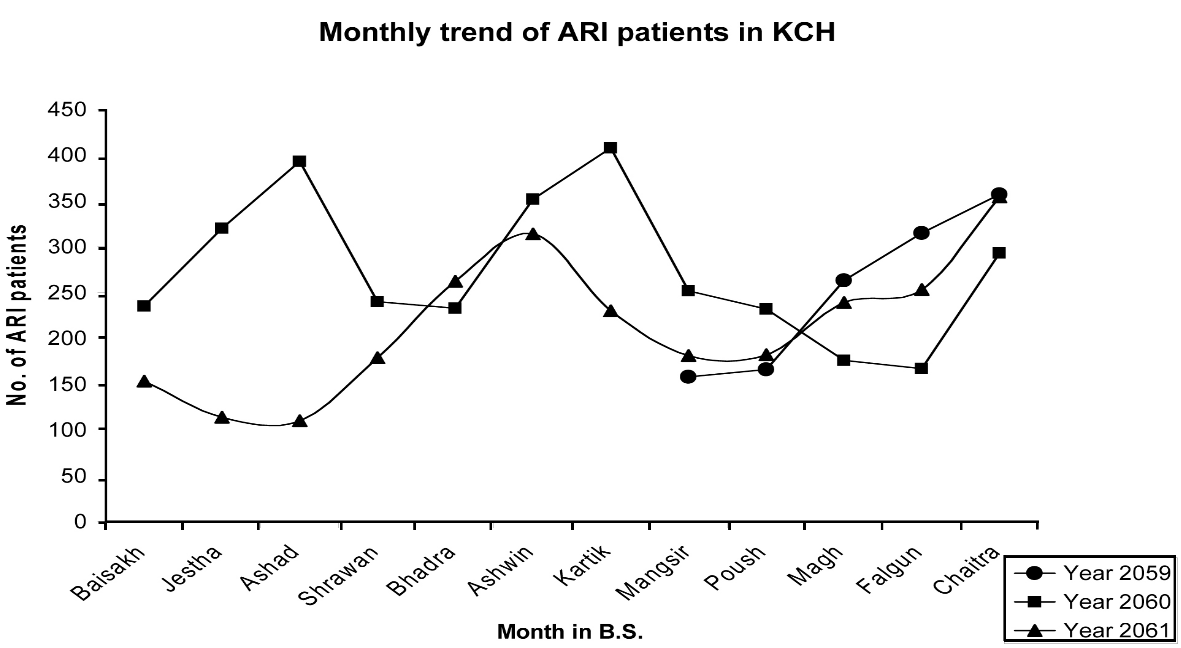
Data from DHS for national incidence of ARI in children for three consecutive years was retrieved and shown in figure 1. Looking at the national incidence of ARI, it is readily evident that there is somewhat constant incidence of ARI throughout the year (estimated coefficient of variation for BS 2060 equals 4.97%). However, this appears to be contrary to that of KCH records (estimated coefficient of variation for BS 2060 equals 28.65%); the total number of ARI patients in KCH shows a volatile fluctuation in accordance to season as apparent from figure 2. It was found that during dry winter and summer months the ARI related hospitalization was high, whereas during monsoon the figure was comparatively low.

figure 1



Source: DHS, 2004.

figure 2



Source: KCH Medical records section, 2005.

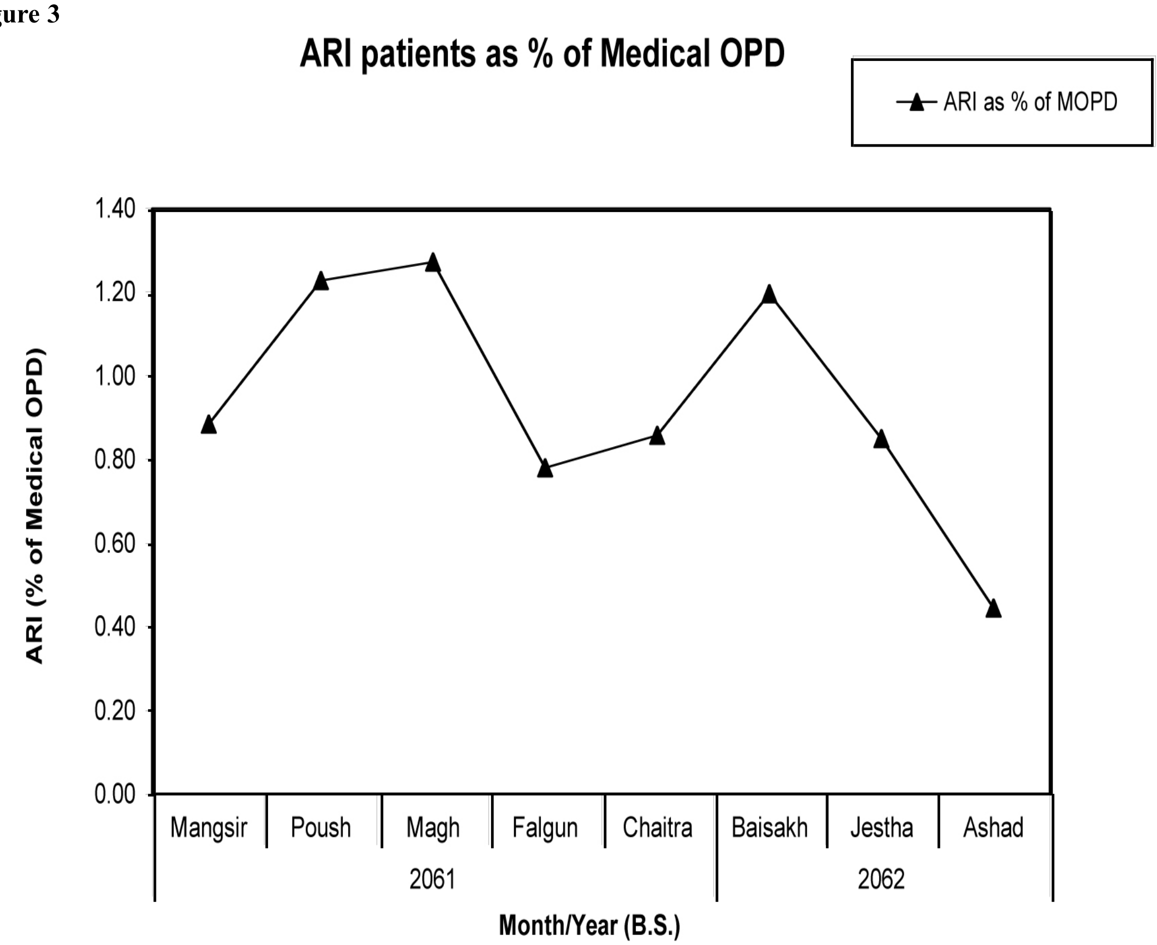
Similarly total number of patients visiting Medical OPD of KCH was obtained and ARI ward admission as proportion of Medical OPD visit was computed (Table1 and figure 3).

Table1: ARI ward admission as percent of Medical OPD

Year	Month	ARI Ward	Medical OPD	ARI as % of MOPD
2061	Mangsir	58	6,555	0.88
	Poush	81	6,600	1.23
	Magh	84	6,605	1.27
	Falgun	87	11,165	0.78
2062	Baisakh	106	8,859	1.20
	Jestha	92	10,822	0.85
	Ashad	48	10,807	0.44

Source: KCH Medical Records Section, 2005.
Note: MOPD = Medical OPD

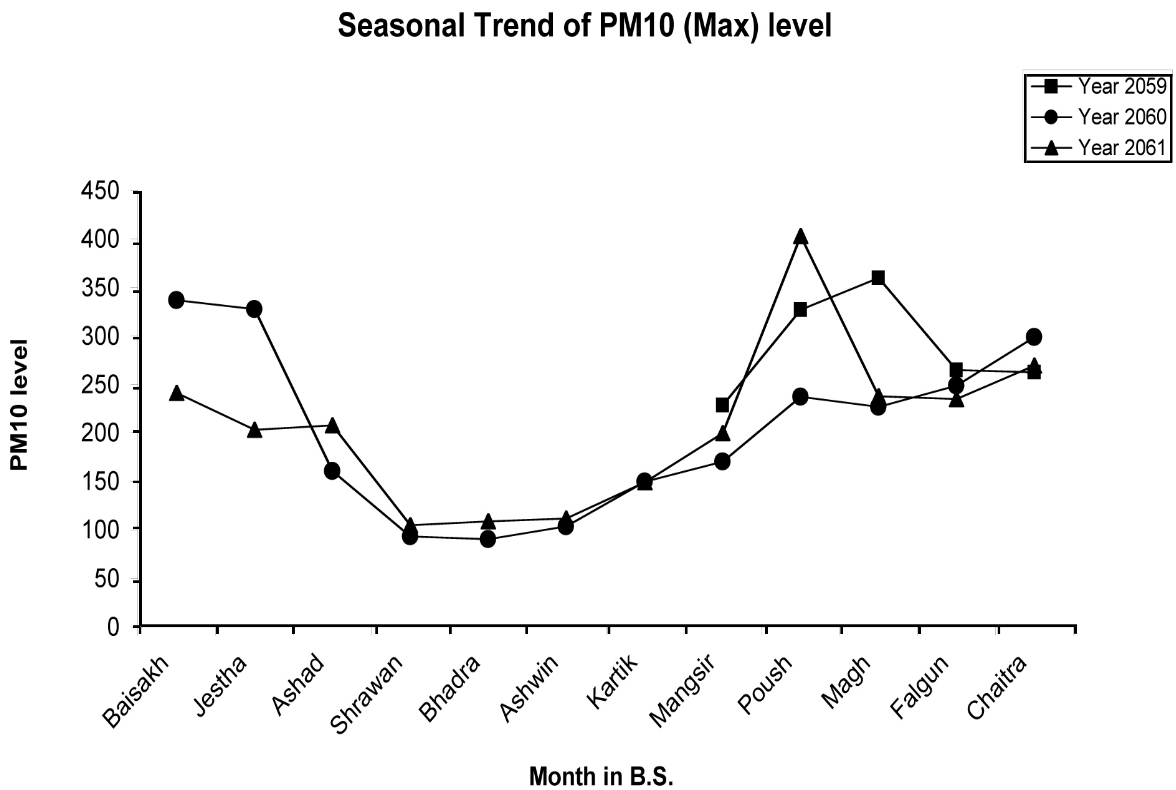
figure 3



Source: KCH Medical Records Section, 2005.

The series also indicated that there was proportionate increase in the number of ARI patients during dry months.

figure 4



Source: MOPE, 2005.

Looking at the monthly or seasonal variation of PM^{10} concentration in the valley, it has a peculiar and somewhat predictable trend. During the dry months of winter and summer PM^{10} concentration was found higher and during monsoon it was found the least. Triangulating the above findings, the PM^{10} level inside the valley seems to control or influence the variability of ARI related hospital admission.

Empirical Analysis

Description of Morbidity, PM_{10} concentration and Meteorological variables:

Summary statistics of morbidity counts, PM^{10} concentration and meteorological measures are shown in Table 2. A total of 7,131 inpatient episode of ARI were included in the analysis. During the period, on an average there were 246 ARI hospitalization per month in the total study population in the study area, and mean PM^{10} concentration was 219 ìg/m³.

Table 2: Descriptive statistics of PM_{10}, morbidity (ARI) and meteorological data in Kathmandu valley (N = 29)

	Minimum	*Maximum*	*Mean*	*Std. deviation*
PM_{10} level (ìg/m³)	90.30	403.00	219.16	85.49
Total No. of ARI Patients	110	408	245.90	81.12
Max temperature (ÚC)	18.3	29.9	24.95	3.94
Precipitation level (mm)	0.0	16.6	4.15	4.85
Relative Humidity (%)	64.7	87.8	80.27	7.02

Note:
N = number of observations
Std. deviation = Standard deviation

Table 3: Correlation matrix (Mangsir 2059 to Chaitra 2061)

	Precipitation	*Max. temperature*	*Relative Humidity*	PM_{10}
Precipitation	1.000			
Max. temperature	0.634	1.000		
Relative Humidity	0.283	-0.272	1.000	
PM_{10}	-0.568	-0.419	-0.457	1.000

Table 3 shows the Pearson correlation coefficient for the monthly values over the entire period among the PM^{10} and weather variables. The results showed that PM^{10} is negatively correlated with temperature, relative humidity an precipitation.

Regression Analysis:

Maximum PM^{10} reading resulted in the highest relationship with morbidity outcome. Therefore, we used the highest PM^{10} in the respective month for the regression model. Using monthly pollutant data, morbidity data and controlling for meteorological variables, regression analysis was conducted for the year 2060.

A multiple (log-liner) regression model was used for the empirical analysis using STATA statistical package with robust standard error, which corrects for the detected autocorrelation and estimates respective robust regression coefficients. The result of the regression analysis is presented in Table 4.

Table 4: Regression output of the Multiple (log linear) regression model with Robust standard errors

Variable	Robust Coefficient	T	Std. Error	P value	95% CI	
ln PM_{10}	0.5746157	2.2	0.261599	0.079	-0.097846	1.247078
ln Precp.	0.0793596	1.29	0.061449	0.253	-0.078601	0.237321
ln Hum.	2.920134	1.4	2.080104	0.219	-2.426944	8.267211
ln Temp.	1.357155	1.86	0.729220	0.122	-0.517365	3.231676
Constant	-14.7204	-1.2	12.31546	0.286	-46.37831	16.9375
Adjusted R^2	0.4564		$F_{(4, 5)}$		8.58	
Root MSE	0.20648		*P value*		0.0184	

Precp. = precipitation level
Hum. = relative humidity
Temp. = temperature
t = t-statistic
CI = Confidence Interval
P = ProbabilityAdjusted R² = Adjusted Coefficient of multiple determination
Root MSE = Square root of the mean square error (=ó^2), i.e., S.E. of the estimate ó^

The Table 5 shows the estimated elasticity of respective variables using the mean value of variables.

Table 5: Elasticities of explanatory variables

Variables	Elasticity	Z statistics	Std. Error	P value	95 % CI		Mean
ln PM_{10}	0.54416	0.25137	2.16	0.03	0.051488	1.03683	5.24755
ln Precp.	0.01231	0.00953	1.29	0.197	-0.00638	0.03099	0.85934
ln Temp.	0.797	0.42957	1.86	0.064	-0.04494	1.63894	3.25414
ln Hum.	2.30305	1.64991	1.4	0.163	-0.93071	5.53681	4.37026

Conclusion

The output presented above indicates that the model is significant at 5 percent level of significance. Similarly, the partial regression coefficient of PM^{10} is positive and statistically significant. Also, a positive and significant elasticity coefficient of PM^{10} was obtained. Both descriptive and empirical analysis pursued gave conclusions in similar direction. Descriptive analysis suggested that, contrary to the year-round fairly equal incidence of ARI at national level, there is a seasonal trend in the incidence of ARI within the valley. This seasonal trend seems to be influenced by the similar seasonal pattern of particulate pollution inside the valley.

Similarly, empirical analysis suggested that there is a positive relation between ARI and PM^{10} level. In an average, a 1 percent point increase in PM^{10}, *ceteris paribus,* results in about 0.54 percent point increase in the number of inpatient ARI cases (95% CI: 0.051488, 1.03683).

Discussion

Previous studies on the topic only gave indicative conclusions and mostly utilized dose-response coefficient developed in other countries[4,16]. The present study is first of its kind as it establishes dose-response relation between particulate pollution and ARI hospitalization. This study partially bridges the gap of baseline study in the study area. However there are some limitations of the study, primary limitation being poor quality hospital and lack of long term pollution data. Due to lack of scientific data pertaining to disease classification some error in the estimation is admissible. Similarly stratification of patients based on the place of residence was not possible because such data is not maintained beforehand in the hospital records. Although systematic recording of data in computer has been started in KCH since Mangsir 2061 B.S., it is not fully functional. Hopefully in near future systematic data will be available for research studies.

Now if we talk about the pollutant concentration in the valley, there is dearth of reliable historical air quality data. So it is difficult to tell exactly how air quality has changed in these days and what would be its position in future. However some scattered data can give some insight regarding this. In November 1992, Environment and Public Health Organization (ENPHO) had collected several 24 hour samples to monitor PM^{10} at nine sites in Kathmandu including Putali Sadak (at 6 m height)[17]. At Putali Sadak, the study recorded the 24 hour average PM^{10} concentration to be 92 ìg/m^3. A decade later MOPE/ESPS monitoring system recorded the average 24 hour PM^{10} level at Putali Sadak in November 2003 and 2004 to be 187.7 and 218 ìg/m^3 respectively[14]. These figures indicate that the PM^{10} level at Putali Sadak has increased by more than two folds over the last decade.

Taking1992 as base year, the author has estimated that the (constant) growth rate of particulate pollution in the valley is 11.41 percent point per year[18]. Using pollution growth rate 11.41 percent and elasticity coefficient 0.544, it is estimated that there will be 6.37 percent point increment in the inpatient ARI cases per year in the valley. The author also estimated that the economic cost of ARI related hospital admission in children for year 2002 and 2003 in the study area amounted to Rs 2 million and Rs 5.4 million respectively.

From the foregoing discussion it is evident that, unless checked, the pollution level will reach at alarming stage in coming years. The higher levels of pollution mean more ARI related hospitalization in children. This, in effect, is going to pose considerable economic burden on the economy and also lead to loss of economic welfare.

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