# I. Study Title

**Valuing Health Benefits of Air Pollution Reduction in Kathmandu Valley**

# II. Investigator


**Naveen Adhikari**

Assistant Lecturer

Central Department of Economics (CEDECON)

Tribhuvan University

Kirtipur, Kathmandu

Phone: (+977) -1- 4330950 (Off.)

(+977) -1- 6635086 (Res.)

(+977)-9851062222 (Mob.)

Email: nabueco@gmail.com


# III. Institutional Affiliation


## Central Department of Economics (CEDECON)

## Tribhuvan University

Kirtipur Kathmandu

Nepal

Phone: (+977)-1-4330950

Fax: (+ 977)-1-4333539

Email: cedecon@mail.com.np

Web: http://www.cedecontu.edu.np


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**Amount Requested:**

**Project Duration: 18 Months**

## 1. Background

It is an established fact that high concentrations of lower atmospheric pollution (e.g. ozone, lead, and particulate matter) pose a threat to human health. The threats to human health are due to morbidity and mortality problems. Prolonged exposure may lead to irritation, headache, fatigue, asthma, high blood pressure, heart disease and even lead to cancer (Shrestha, 2001). And, such pollution has not only the negative physical impact on environment, but also has economic costs arising through the loss in productivity, loss in working days due to illness, treatment cost for illness and finally loss in wages.

Along with the pace of rapid urbanization, air quality in Kathmandu valley is deteriorating leading for health hazards risks. The various sources of increasing air pollution in Kathmandu valley include vehicular emissions, poor infrastructure, re-suspension of street dust and litter, black smoke plums from bricks kilns and refuse burning (Shrestha, 2001). Among these various sources, the threats to human health are basically from vehicular emissions. Vehicular growth during the last few years and poor infrastructure of Kathmandu valley are significantly causing for deteriorating air quality in Kathmandu valley. The number of vehicle has been growing at a rate of 17 % each year with no corresponding concerned given for the devolvement of infrastructure in the valley (MOEST, 2005). At the same time, brick kilns are also under operation with in valley adding to the deteriorating air quality in Kathmandu valley. Besides, the complex topography of Kathmandu often dictates the flow of the lower atmosphere resulting into limited air pollution dispersion. This has made the air pollution control more challenging in the valley. Nonetheless, vehicular emissions is seen as major source of air pollution in the valley and most of public interest and policy often has centered on controlling vehicular air pollution.

Keeping the increasing air pollution in valley, the government of Nepal has already implemented some of the policies to control the deteriorating air quality in

Kathmandu valley. These initiatives are primarily targeted on controlling vehicular emissions and operation of brick kilns, which are seen as major sources of air pollution in Kathmandu valley. A number of initiatives have been taken by MOEST in order to improve the air quality, which among others include mainly, enactment of Industrial and Environmental act, vehicle emissions exhaust test, ban on three wheelers diesel tempos, introduction of electric and gas powered vehicles, import of EURO-1 standard vehicle, ban on new registration of highly polluting brick kilns etc.

In these contexts, it is of important question to ask whether government's various environmental policies to control the air pollution in valley has worked or not. At the same time, monetary estimate of benefit can be useful information to different stakeholders in regard to air pollution regulation initiatives and their enforcements in other growing cities in Nepal. This would also provide the base for long term alternative energy initiatives in the valley.

## 2. Research Questions

The study makes attempts to answers following research questions:

- Whether the ban of gross polluting vehicles has decreased the air pollution in Kathmandu valley?
- What are the monetary benefits and costs of such ban policy by the government?
- What are the benefits to households of Kathmandu valley if the air pollution is reduced to the safe level?

## 3. Objectives

Given the context that government of Nepal has already taken some policy measures to control the air pollution and still air pollution is Kathmandu valley is far above the safe level seriously causing a negative health impacts in terms of Morbidity and

Mortality, the research is primarily concentrated on valuation of health cost due to air pollution in Kathmandu valley. The specific objectives of this study are:

- To examine effect of different government policies to control air pollution in Kathmandu valley in terms of health benefits.
- To measures the health benefits to the household of Kathmandu valley from reduced air pollution to safe level

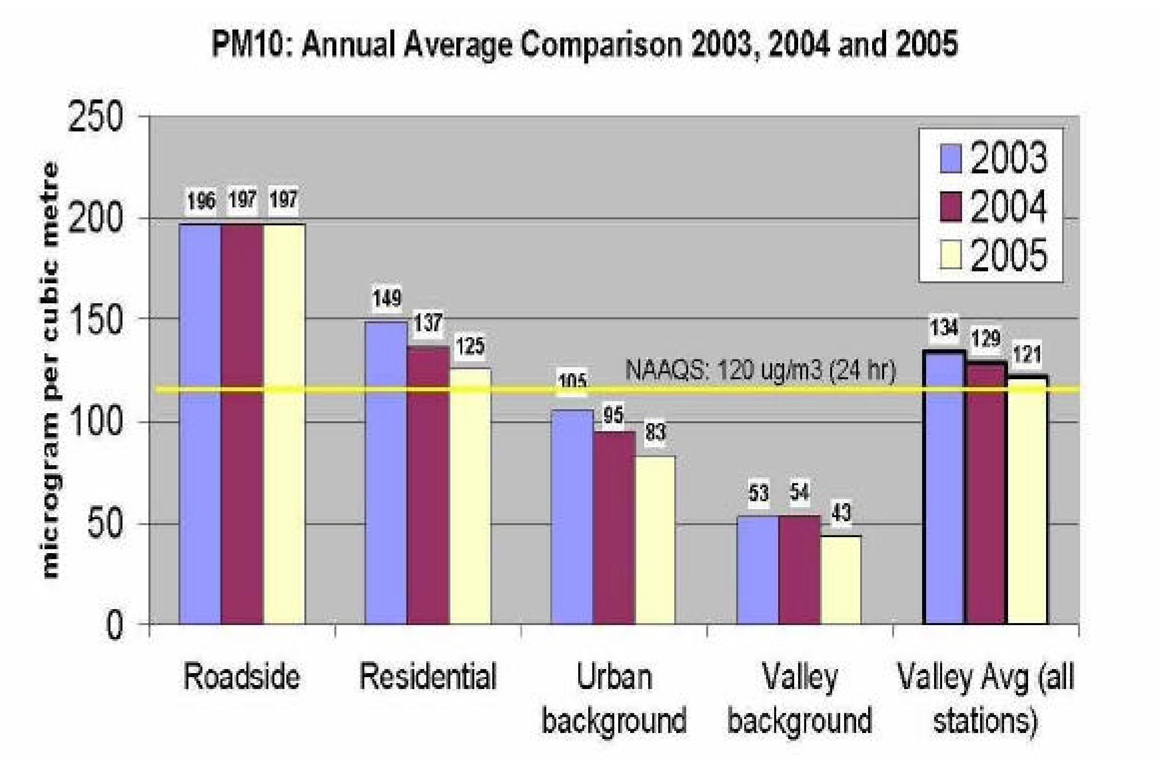
## 4. Study Area

Kathmandu valley, which consists of three administrative district of Kathmandu, Lalitpur and Bhaktapur, is fastest growing major urban area in the country. It is bowl-like in topography, lying at a height of around 1300 meters. The complex topography of Kathmandu often dictates the flow of the lower atmosphere and accordingly air pollution dispersion is often limited.

The rapid population growth and poor infrastructures are fueling the intense of pollution in valley ranging from air and water pollution to solid waste management. The population grew nearly by 50 percent during last decade (CBS: 2006). Over the year, there has been significant increase in the number of vehicles (as high as of 17 %/ year) leading for high emissions, which is seen as major source of air pollution in Kathmandu valley.

The annual report published by Ministry of Environment, Science and Technology showed that air pollution levels in Kathmandu Valley are very high, especially during the dry season. Among various parameters monitored, the particulate matters are found generally to exceed the national ambient air quality standards (NAAQS) on the core city area. For example, annual average PM10 level was found to be as high as of 197 ug/m3 on road side stations ( Putalisadak and Patan) in 2005. The concentration is still high on the residential area above the safe level (Figure 4.1). The spatial feature of air pollution in Kathmandu valley is that it varies significantly across the seasons and locations. The concentration of air pollutants on dry season generally falls in a unhealthy range ( up to 349 ug/m3) while it decreased significantly during rainy seasons. Similarly, it also varies significantly across the different location of Kathmandu valley. For example, one of the monitoring stations in Valley, Matchhegaoun generally records a safe level of PM10 (valley background in figure 4.1).

**Figure 4.1 PM10 on different locations**




*Source: MOEST, 2005*

Among various parameters of air pollutants, it is concluded that the main concern of air pollution in relation to human health is the very high levels of respirable particles (PM10/PM2.5) in Kathmandu valley. The report of MOEST (2005) also shows that the excess total mortality due to the levels of PM10 in outdoor air Kathmandu was about 900 per 1,000,000 inhabitants in 2003 and if the concentrations of PM10 in Kathmandu Valley could be reduced to levels below 50 µg/m3, 1,600 deaths out of the total population of 1.8 mio. Could be avoided, based on the levels of PM10 found in 2003 (MOEST, 2005).

## 5. Review of Literature

The benefits from improved ambient air quality are quite established. The reduction in ambient air pollutants level has the benefit to human in terms of reduced morbidity and mortality, which in turn increases the productivity, improved agriculture productivity, reduce soiling and material damage and improved visual amenities. The estimation of health benefits (or costs) can be done in four steps (Ostro, 1994). The first step is to relate human health to ambient air pollution level through dose response function. Once the slope of dose response function is estimated, next step is to estimate the number of people who are exposed and susceptible to the particular air pollution effect being considered. The third step is to estimate the change in air pollution level under consideration, which might be due to implementation of a particular air pollution reducing strategy, or simply a change in air pollution from current level to some standard level. Product of these three factors gives us the change in population risk of health effect under consideration. Finally, the economic valuations are developed from estimates of the willingness to pay for reducing air pollution level, or cost of illness due to air pollution.

Only few studies have been done on air pollution in Kathmandu valley mainly considering the biological aspects. At best, these studies have centered on the dose function approach only. Hildebrandt et.al. (NA) under the title "Climate and Air Quality: A Case Study of Pm10 Pollution in Kathmandu, Nepal" have examined seasonal concentration and transport of anthropogenic PM10 in Kathmandu, coupled with an examination of the climate and the physical geography of the region. They found that that intra-seasonal variation in climate plays a large role in directly and indirectly controlling ambient particulate matter levels. Variables such as temperature, wind speed and direction, and precipitation affect the concentrations of PM10. Murthy et.al (2003) on their study 'Valuation and Accounting of Urban Air Pollution:

A Study of Some Major Urban Areas in the Indian Subcontinent' following household health production function, found that the estimate of MWP for a representative household from Katmandu is Rs.19.08 while estimates of annual benefits to a representative household by reducing PM10 concentration from the current level to the safe standard of 100µ gms/m3 PM10, the annual welfare gains to a representative household from Katmandu is Rs.1905.3512.

Nonetheless, there is still gap for economic valuation of air pollution in Kathmandu valley considering various air pollutants parameter. Moreover, no study has made any attempt to examine the effect different government policy to improve air quality in the valley. This study is intended to fulfill the gap in two ways: firstly, examining the effect of government policy and finding the health benefits of reduction in air pollution considering continuous and more reliable data set on various air pollutants.

## 6. Methodology

### 6.1 Hypotheses

In line with objective of the study, following hypotheses will be tested on the study:

- Government policy of banning gross polluting vehicles has monetary benefits through the reduction in air pollution.
- Improvement in air quality reduces health cost in terms of reduction in lost earnings due to absence from work
- Improvement in air quality reduces health cost in terms of reduction in cost of various averting activities
- Improvement in air quality reduces health cost in terms of reduction in cost of mitigating activities

### 6.2 Theoretical Framework

Most of the studies rest on the use of standard household production on measuring the benefit of air pollution reduction. However, a simplified version of general health production function will be used in this study following Murthy, et al (2003) specified as:

$$H = H(Q, M, A; Z) \quad (1)$$

Where, H = health status refers the days of illness, is considered that health status of household (H) is positively related to the level of air quality. In the function (1), mitigating activities (M) include individual's demand for medicines, hospitalization, pathological tests, doctor's consultation and travel to doctor's clinic. Averting activities (A) is the attempt to reduce exposure to pollution which includes number of days stayed indoor to avoid exposure, extra miles traveled in a day to avoid polluted areas in the city, using a gas mask while traveling, etc. Z is a vector of individual characteristics captures factors like individual's baseline health which in turn affects individual's ability to offset exposure to pollution through averting activities.

The utility function is defined as

$$U = U(X, L, H, Q, Y) \quad (2)$$

,with X= consumption, L = Leisure, H= Health Status, Q= Air Quality and Y= individual's income.

The individual budget constraint is expressed as:

$$Y = Y^* + w(T-L-H) = C + P_a A + P_m M \quad (3)$$

Where w is the wage rate, $P_a$ & $P_m$ are the price of averting and mitigating activities respectively and the price of aggregate consumption is normalized to one.

Here individual Maximizes the utility function subject to the budget constraint choosing C, L, A and M. following Lagrange's multiplier, the first order conditions yields following demand function for mitigating and averting activities being dependent on  The individual allocates his non-labor income(Y*) and labor income between aggregate consumption (C), averting activities (A) and mitigating activities (M) as:

$A = A(w, P_a, P_{m,} H, Q, Y, Z)$ (4)

$M = M(w, P_a, P_{m,} H, Q, Y, Z)$ (5)

It then followed that individual's willingness to pay (WTP) for a small change in pollution is comprised of individual's marginal lost earning, marginal medical expenditure, marginal cost of averting activities, and monetary value of disutility caused by illness. The expression can be established as:

$$WTP = w\frac{dH}{dQ} + P_m\frac{dM}{dQ} + P_a\frac{dA}{dQ} - \frac{U_H}{l}\frac{dH}{dQ} \quad (6)$$

As the monetary benefits from the reduction in discomfort is somehow quantitatively not measurable, the monetary benefits from the reduction in air pollution is generally captured by first three expression of (6).i.e.

$$WTP' = w\frac{dH}{dQ} + P_m\frac{dM}{dQ} + P_a\frac{dA}{dQ} \quad (7)$$

For the fact that cost of averting activities can not measured so accurately, the general practice is to consider the lower bound of estimates called cost of illness (COI) as

$$COI = w\frac{dH}{dQ} + P_m\frac{dM}{dQ} \quad (8)$$

This study aims at measuring the benefits as indicated by (7), which includes the averting expenditure (the medium scenario). This measure of benefits comprises the lost earning due workdays lost, medical cost and cost of averting activities.

## 6. 3 Sampling Design and Data Collection

For this study, two types of data are required:

- Household information on health /sickness and a number of household characteristics
- Air pollution data.

The required air pollution data like TSP, PM10, and PM2.5 etc will be collected from the Ministry of Environment, Science and Technology (MOEST). From October 2002, the government of Nepal, in support of DANIDA, has been implementing a long term air quality monitoring program in Kathmandu valley. The outdoor air pollution level in Kathmandu Valley is currently being monitored for Particulate Matter (Total Suspended particulate, PM10, PM2.5), Gaseous Pollutants (Nitrogen Dioxide, Sulfur Dioxide, Carbon Monoxide, Benzen) and Toxic Micro pollutants (Lead, Polycyclic Aromatic Hydrocarbons, Meteorological Data). However, continuous data is available fro TSP and PM10, while information on others are gathered for samples period.

Currently, there are six monitoring stations located at different part of city namely Putalisadak, Patan, Thamel, Kirtipur, Matchegaoun and Bhaktapur. Among these monitoring stations, only three are located on core city where there is high concentration of vehicular movements as well as population. Therefore, required air pollution data from these monitoring stations viz. Putalisadak, Patan and Thamel would be collected.

The household information would be collected from the households residing nearby the monitoring stations form which air pollution data is collected. The selected households, then, will be surveyed using questionnaire to collect data on health expenditure, illness, mitigating behavior, and other household characteristics. The sampling procedure that will be used for survey is based on two-stage stratification-air pollution monitoring stations and type of accommodation as in Gupta (2006). As mentioned earlier, out of six monitoring stations in Kathmandu valley, three viz. Putalisadak, Patan and Thamel will be selected in first stage. The households located within 1 kilometers radius of monitoring stations will be selected for required household information. Besides, stratification according to type of accommodation will be done. Based on the type of dwelling for the household within the kilometer radius of monitoring stations, households will be selected randomly proportional to the total number of households in the respective house type.

## 6.4 Estimation Techniques

Theoretical framework suggests that there is the requirement for the estimation of health production function and two demand functions for mitigating and averting expenditure. The estimation will be done in two way following Gupta (2006). The first technique is to estimate equations separately using one the limited dependent variable estimation procedures. Accordingly, Logit, Probit, Tobit or Poisson regression model will be used, which will depend on nature of the dependent variable. The second technique is to estimate all three equations jointly in a simultaneous equation model using 3SLS or GMM estimation procedures.

Following Gupta (2006), three regression models will be used to H, M and A. Specifying, H as function of number of sick days, number of doctor visits and number of workdays lost due to illness, a poission regression model can be used as:

$$H_{it} = E(H_{it}) + u_{it} = l_{it} + u_{it}$$
$$\ln l_{it} = b_1 \ln X_{it}$$

where $l_{it}$ is the mean value of number of sick days, or doctors visits, or workdays lost, $b_1$ is vector of regression coefficients and $X_{it}$ is the vector of independent variables.

Folliwing Tobit model, demand for mitigating activities can be estimated as:

$$M^*_{it} = X_{it} b_2 + u_{it}$$

where $M^*_{it}$ is a latent variable with

$$M_{it} = M^*_{it} \qquad \text{if } M^*_{it} > o$$

$$0 \qquad \text{if } M^*_{it} \leq o$$

,where $b_2$ is vector of regression coefficient and $X_{it}$ is the vector of independent variable.

The demand for averting expenditure can be used following probit model specified as:

$$\Pr(A_{it} = K = f(X_{it} b_3)$$

Where $A_{it}$ , denotes the degree of averting behavior for individual i at time t, β3 is the vector of regression coefficients, xit is the vector of independent variables, and f(.) is the standard normal cumulative density function.

Here both one way and two way error component can be used to capture the affect of unobservable households characteristics and unobservable time specific effects.

Furthermore, following Murthy, et al (2003) and Gupta (2006), we can also estimate the household health production function model by considering the health production function and the demand functions for mitigating and averting activities as simultaneous equations in H, M and A using the 3SLS method of estimation. The estimated model is as follows:

$$H_{it} = b_H x_{it} + g_{12} M_{it} + g_{13} A_{it} + u_{Hit}$$
$$M_{it} = b_M x_{it} + g_{21} H_{it} + g_{23} A_{it} + u_{Mit}$$
$$A_{it} = b_A x_{it} + g_{31} H_{it} + g_{32} A_{it} + u_{Ait}$$

where, xit is the vector of independent variables, β() are the vectors of regression coefficients for independent variables, and ϒ() are the regression coefficients for H, M and A. To capture the unobservable individual specific and time variant effects on independent variables, we can use one-way or two-way error component model as mentioned before. With the estimation of parameters so specified above, the WTP and COI can be calculated.

## 7. Policy Relevance

Government of Nepal has been initiating various environmental friendly policies so as to improve the air quality in Kathmandu valley. The government of Nepal has been preparing to apply EURO-II and III standard vehicle in Kathmandu valley. As such, government has already been taken some of initiations specially on controlling vehicular air pollution. These air pollution controlling policies through the ban of gross polluting vehicles have costs as well. Thus it is an important question to ask whether such policy has reduced the air pollution in the valley and what are the health benefits associated with such reduction in air pollution. Under the background of government initiation to have a master plan for alternative energy strategies, the measures of health benefit through the reduction of air pollution to safe level. would be an useful information for policy makers.

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