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Air Pollution Reduction and Health Impact Analysis

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ABSTRACT

The project involves the study of health impact due to air pollution in West Delhi. Air pollution causes deterioration in the health status of people due to which a major proportion of their income is incurred on medical expenditure. The major objective of the project is to approximately assess the benefit that an individual would get in West Delhi, if there is a decrease in air pollution here, or similarly reiterated, an increase in the air quality of West Delhi. The research methodology involves household production function model which is based on household survey of areas which are within half a kilometer distance from the main air pollution monitoring stations of CPCB (Central Pollution Control Board) and DPCC (Delhi Pollution Control Committee) located at Punjabi Bagh, Janakpuri and Shadipur. Also, indoor pollution, ambient air pollution and poor health stock increases the probability of falling sick. This reduced probability of falling sick implies a monetary benefit that individuals will get as a result of reduction in Air Pollution. Various factors, including nutrition, eating habits etc. have a positive relation with the number of sick days that a person has, and an increase in the aforementioned independent activities increases the dependent variable (no. of sick days) in the same direction. The study holds a significant role in spreading awareness about air pollution among people in Delhi and helping us identify reasons for high indoor pollution in various regions of Delhi. By safeguarding the health of individuals, the society would contribute building up of human capital which is more productive and efficient, since health is a crucial constituent of human capital. The study could be extended to weekly health status of individuals since outdoor pollution variable changes daily. Therefore weekly averages of PM2.5, NOx, SOx could be sent for analysis.
KEYWORDS: Air pollution, Health Production Function, Household surveys, Nutrition

INTRODUCTION

Delhi, the Capital of India, is also a hub of economic activity and at the same time is overloaded with migrants from various parts of India, and also from overseas. The uniqueness of Delhi lies in its capacity of accommodating various migrated individuals and also facilitating them in their contribution to our productive economy. Delhi has been expanding tremendously and thus witnessing spectacular speed of urbanization. With a massive population of about 18 million people for an area of about 1500 kilometers squared, we have a very high population density and huge scarcity of resources as well as overutilization of the available ones. In addition to the aforementioned phenomena, the air quality in Delhi has been the worst of any major city in the world.

Nutrition is one of the crucial determinants of the health status of an individual and a prudent diet could reduce the deleterious impact of air pollution on health. With air pollution being a major problem in Delhi, the present study attempted to include the nutrition factor in calculating health benefits out of mitigating air pollution. The importance of nutrition for a healthy life has been translated into dietary recommendations indicating that one should balance calorie intake with physical activity, prefer vegetables, fruits, fiber and fish and restrict saturated fat, salt, and added sugar intake. However, behavior change is very difficult to implement, and hence it is difficult to assess the impact on health.

Westernized diets, popular in today's culture in Delhi, are characterized by a low intake of fruit, vegetables, wholegrain and fish, and a high intake of processed food items, resulting in low intake of favorable nutrients such as omega-3 PUFA and antioxidants (e.g., carotenoids and flavonoids). This lessens protection against inflammatory problems, such as air pollution. Air pollution leads to both oxidative stress and inflammation, which are pathologies underlying asthma and exacerbations of asthma. Hence, increasing the intake of nutrients with antioxidant and/or anti-inflammatory properties has the potential to improve asthma management. Various studies have shown that some nutrients such as Vitamin B, C, E and D and Omega- 3 PUFA have protective effects against the damages induced by particulate matter [(8)]. In a polluted environment a healthy diet with adequate intake of essential micro nutrients may be critical to prevent the development of chronic diseases, particularly cardiovascular and pulmonary diseases.

Delhi's air quality has been a cause of worry for both its residents and the Delhi Government. With the ban imposed on Diesel vehicles and the odd-even scheme that was tried in Delhi from January 1st to January 15th, 2016, we can see that the levels of pollutants in the air has risen so much that the Government has to now think of implementing such strong measures in the NCR region that affects major sectors of the economy and is a problem for the common people as well.

With a large population at our disposal, that cannot be easily refrained from causing pollution, we can instead try to utilize our strength and give the people a proper incentive that drives them to try and curb the pollution that is increasing every second in Delhi. We need to understand that to properly curb this pollution for a long term; we need to work at the grass root level that is the household level for Delhi. There should be an incentive for each household to try to mitigate air pollution.

Epidemiological studies have focused on establishing a Household Health Production Function and Pollution Control Models through analysis of cost and damage approach, or a physical linkage approach, and other different techniques (A.K. Haque, M.N. Murthy, P. Shyamsundar: Environmental Valuation: A Review of Methods,), (A. Myrick Freeman III, Robert H. Haveman, Allen V. Kneese: The Economics of Environmental Policy).[(6)]

An interesting study which is very similar to this project is done by Usha Gupta (2006) for the Kanpur City in Uttar Pradesh, India.[(5)] The study measured the monetary benefit to the people of Kanpur, as a result of decrease in health damages being a consequence of reduction in air pollution. With a recall period of 6 months and maintenance of weekly health data of the people through regular entries in health diaries, the paper estimated a gain of INR 310 million per annum to the population of the Kanpur city from reduced morbidity if air quality were improved to meet the NAAEs standard. However, the study didn't include expenditures on avoiding activities and the opportunity cost of time associated with medical care.

In another study, Murty, et. al. (2003) [(7)] estimated a household health production function model for measuring economic benefits from reduced air pollution in the Indian cities of Delhi and Kolkata. Using six months of data relating to sick days, averting and mitigating activities, they estimated a system of simultaneous equations. The results showed a monetary benefit of INR 4897 million for Delhi and INR 3000 million for Kolkata if the level of suspended particulate matter in the air was reduced to safe limits.

Based on the Gerking and Stanley (1986) model and the dose response method, Kumar and Rao (2001) also measured the monetary benefit of air quality improvement in Panipat Thermal Power Station colony in India. They estimated Willingness to Pay for reduced levels of pollutants (PM10) in the ambient air, which came out to be INR 21 to INR 52.5 per month for a sixty seven percent reduction in the ambient mean concentration of PM10.

Min Bikram Malla Thakuri in Kathmandu (September, 2009) study was based on carbon stoves and pollution the study predicted a strong correlation between CO and PM10 levels, and also that the indoor pollution is one of the major contributors of many health problems, resulting in high expenditure in terms of treatment and loss of productivity and efficiency.

A study on the Social Cost-Benefit Analysis of the Delhi Metro (Murty, 2006) emphasizes the saving in fuel consumption due to the use of the Delhi Metro as a mode of transport. The inter fuel substitution of petrol and CNG to electricity not only results in savings of foreign exchange and also facilitates in mitigating air pollution. The paper was based on the annual run and consumption norms of different vehicles in Delhi. The estimated fuel saved due to the diversion of traffic of cars and two-wheeler vehicles is 138.35 and 25.70 litres, with fuel savings for cars, buses and two-wheelers are INR 5260, INR 710, and INR 9770 million, respectively.

Murty and Myrick Freedman III used the Hedonic Property Price Approach while investigating the role of climate change and thereby making climate enter utility functions. Some measures of climate as explanatory variables in the function were incorporated, thus taking advantage of the substantial variation in climate across some urban areas by pooling data from several cities. Murty 'Measuring Green GDP' (2007) computed an index of economic growth with the environmental results of that growth factored into a country's conventional GDP. It monetizes the loss of biodiversity, and accounts for the costs caused by climate change, basically subtracting resource depletion and environmental degradation from the traditional GDP figures. It approached the idea that the environmental damages are site specific and the population density and actual pollution load determine the benefits from the reduction of a ton of particulate matter. A similar dose response function and medical expenditure function was estimated to find that a minimum of NRS 266 per year was the welfare gain to an individual in the city from reduction in air pollution. Naveen Adhikari (2012) on similar path carried on a research in Kathmandu Valley, citing the 'health' benefits to a person from reducing air pollution.[1]

welfare benefit to the people when they try to reduce pollution in any form. A study by Purnamita Dasgupta (February, 2004) shows similar assessment of water pollution and water borne diseases in Delhi, with a health production function approach.[2] The purpose of utility maximizing behavior is to estimate the probability of illness for a household, which is further analyzed to derive treatment costs and the wage-loss arising from illness. A similar approach has been seen in the studies involving air pollution as well.

All the above mentioned studies have failed to incorporate the Nutrition status of the household and its role in combating the lower air quality levels. Delhi has witnessed an excessive urbanization resulting in immense rise in indicators of pollution with a massive population of about 18 million people for an area of about 1500 kilometers squared; we have a very high population density and huge scarcity of resources as well as overutilization of the available ones. In addition to the aforementioned phenomena, the air quality in Delhi has been the worst of any major city in the world. Motor Vehicle emissions are considered to be a significant cause of poor air quality in Delhi. 80% of the PM 2.5 air pollution is caused by vehicular traffic, according to some reports. Other causes include exhaust from nearby industrial areas, burning of garbage, dust from construction sites etc. The decreasing air quality has had an irreversible damage on many residents of the city. This includes lung damage, skin damage, lowering of children's intelligence quotient etc.

METHODOLOGY

The study is based on Health Production Function Model in order to assess the impact of both indoor and outdoor air pollution. Grossman (1972) developed the first Health Production Function and used by Cropper (1981) by including pollution as one of the inputs. Gerking and Stanley (1986) and Harrington and Portney (1987) have used this model to determine the relationships among the willingness of the people to pay for a reduction in pollution, cost of treatment, both direct as well as indirect costs. The only difference in all the models which use pollution as an input is whether the variable is used as a direct utility provider or as an indirect one. They also differ with respect to whether the costs of mitigation and averting are included in the pollution variable or not, or if health is taken as a capital variable.

Regression refers to measuring the relation between the mean value of one variable and corresponding values of other variables.The method of computing the monetary benefit of reducing air pollution involves the regressing number of sick days on environment quality, mitigating activity, stock of health capital and stock of social capital.

The source of the data is common households, those which lie within half a kilometer vicinity of any of the air pollution monitoring sites taken under consideration. The health production function that was developed after careful study of external and internal factors that affect the air quality in Delhi gave us various parameters to look after when considering the causes and effects as well as a cost-benefit analysis of air pollution.

Consider a general model in which environmental quality E, mitigating activity M, and aversion activity Av, stock of health capital k, and stock of social capital's, are inputs of the health production function Z.

$$Z= Z\ (E, M, Av,k,s)$$

where Z represents the number of sick days.

Pollution affects individual utility indirectly through the health production function and directly by affecting outdoor recreation and many other services. The utility function of the household is defined as

$$U= U(X, Z, E, L, I)$$

Where X is a private good other than M and Av consumed by the household, L is the leisure, T is the total time. The private good X is given as a numeraire. The budget constraint of the household is

$$I = I^* + w(T-L-Z) = X +PmM+PaAv$$

Given the environmental quality E, and the aversion level Av, human resource capital's, income I, prices w, Pm, Pa, the individual maximizes utility with respect to X, M, Av and L, given the budget constraint. The solution for this equation yields the demand function for mitigating activities and averting activities of the household.

$$\text{Max } G = U\ (X, Z, E, L, I) + \lambda(I^* + w(T-L-Z) - X + PmM +PaAv)$$

The first order conditions are given as:

$Uy = \lambda$

$U_L=\lambda w$

$U_Z.Z_M=\lambda Pm+\lambda wZm$

$U_Z.Z_{Av}=\lambda Pa+\lambda w\ Za$

From the first two conditions, we get

$\lambda Pm/Zm = \lambda Pa/Za = Uh - \lambda_w$

The indirect utility function V is given as

V = V (E, Pm, Pa, S, I, k)

By taking the total differentiation of this function and equating it to 0, we get,

$-Vq/Vi = -Vq/\lambda = dI/dE$

Also, $Vq = Uq + Uh.Zq - \lambda wZq = Uq + (Uh - \lambda w) Zq$

Substituting the value of Vq,

we get, $dI/dE = -Vq/\lambda = -(Uq/\lambda + Pm.Zq/Zm) = -(Uq/\lambda + Pa.Zq/Za)$

By totally differentiating the household production function and equating it to 0,

we get, $Zm.dM + Za.dAv + Zq.dE = 0$

For Av at optimum, $-Zq/Zm = dM/dE$

And, for M at optimum, $Zq/Za = dAv/dE$

dI/dE, the marginal willingness of an individual to pay for the reduction in environmental pollution or an increase in air quality, is the sum of direct utility gains and the indirect benefits from reduced health status through reduction in expenditure on either mitigating activities or averting activities.

Delhi has various monitoring stations to measure ambient air pollution level, managed by institutions like Central Pollution Control Board (CPCB), Delhi Pollution Control Committee (DPCC), and others. The sites for household data are located close to (within half a kilometer) the monitoring station so that the household data are matched with outdoor pollution data to estimate welfare benefits.

There are about 17 sites approximately across Delhi where the monitoring stations are located. Each site has a monitoring station, located on the roof top of a building located at the center of the region, mostly the Electricity Board Centre. Each station has a device which provides the ambient air quality data in form of air quality indicators like NOx, SOx, CO, PM2.5, PM10, and Ozone. These are the indicators of outdoor pollution.

Three sites namely Janakpuri, Shadipur and Punjabi Bagh were considered for the survey. These sites have been chosen for their high pollution levels due to presence of a number of industries and filthy conditions of the nearby located slum areas. The lower income households fail to afford pollution averting devices such as chimneys, exhaust fans, masks etc. which causes serious impact on health of people in West Delhi. These buildings provide the center point for our survey, from which we measured approximately 0.5 kilometers and conducted the survey in the circular area with a team of about 30 students. About 50 households were surveyed from each site, each chosen randomly without any pattern.

The areas covered at SITE 1 Punjabi Bagh (PB) are Railway colony, Power House, Golden Park, Rampura. The areas covered at SITE2: Shadipur (SP) are Ranjit Nagar, Baljit Nagar, West Patel Nagar, Slum area near Metro station (New Patel Nagar). The areas covered at SITE 3 Janakpuri (JN) are A Block, Milap Nagar, Ansalpur Village, Pankha Road, Block, Nangli Jalib, Vikaspuri, Police Colony.

The households were randomly picked up and they were questioned using a well – framed questionnaire prepared strategically for the purpose of the study. Face to face interview was conducted by the team of surveyors. The survey questionnaire had household information regarding total no of people living in that household, type of house, location etc. Second section included health factors like general health information, diseases, and health insurance, nutrition and food habits. Selection three dealt with indoor pollution measured by use of electronics, sanitation products, fuels, furniture, fumigation, paints. The last section dealt with outdoor pollution incorporating number of vehicles and ambient air quality.

Formulation of Study Model

Data about the health status and socio- economic characteristics of household are obtained

through household survey at the selected sites .The study survey was conducted during the month of December and a sample of total 52 households in total from three sites have been selected resulting in total sample of 230.
The data collected can be incorporated under the following variables Endogenous Variables:

1. Health Status is reflected by total number of sick days and total number of visits to hospital.
2. Mitigating Activity reflected by Medical expenses. This includes the following heads:
   a. Travel cost to doctor‘s clinic
   b. Total time waiting and travel
   c. Doctor’s fees
   d. Cost of medicine
3. Averting activities: These are reflected by the following heads:
   a. Daily extra km travelled
   b. No. of days stayed indoor
   c. Use of mask, air purifier
   d. Mode of transport

Exogenous Variables

1. Outdoor Pollution: This parameter can be captured by air quality data provided by CPCB. This is data on SO2, NO2, PM2.5, PM10, CO, Ozone. In this study, we take PM2.5 as an indicator of outdoor pollution.
2. Health stock Index: It is the index of chronic diseases; it also determines the health capital. Chronic diseases are the following (in order): Asthma, BP, Heart Disease, Cancer, Eye disease, TB, Diabetes, and others. (This ranking has been confirmed by Dr. Peeyush Jain MD, DM. Director, Cardiology, Fortis Escorts Heart Institute, New Delhi)
3. Exercise Dummy: It represents if an individual follows an exercise regime as a ‘yes’ or ‘no’ category.
4. Nutrition habits: An index is calculated using the nutrition habits of households like consumption of green leafy vegetables, olive and refined oil, fruits, nuts and processed food (in order). It also incorporates consumption of vitamin supplements by individual. Higher the Index, poorer is the nutritional status of the person.
5. Indoor pollution: An Indoor Pollution index is calculated using the electronic appliances used by households, type of fuels used, garbage system used in th3e house and other sanitation habits.
6. Annual Income: Annual Income is reported from each household.

The aim of the study can be accomplished by running the following regression-

In $(\textit{dayofsickness}) = \alpha_1 + \beta_1 \ln(\textit{outdoorpol}) + \beta_2 \ln(\textit{chronicdiseaseindex}) + \beta_3 \ln(\textit{nutritionindex}) + \beta_4 \ln(\textit{indoorpol}) + \beta_5 \ln(\textit{awarenessofairbornediseases}) + \beta_6 \ln(\textit{mitigationactivity}) + u_i$

RESULTS

Results of Regression Analysis

Nutrition Index holds a positive relationship with number of sick days indicating that as value of nutrition index increases by 1 percent, showing a poor nutrition status, the number of sick days also rises by 1.422 percent.
Number of sick days is also positively related to Indoor Pollution Index showing that as indoor pollution increases by 1 percent the number of sick days rises by 0.002 percent.
Number of sick days are also positively related to health stock indicating that 1 percent rise

in health stock (a person suffering from chronic diseases) would lead to 0.392 percentage increase in sick days.

Table I: Impact of Pollution and Nutrition on sick days

	Coefficient	**Standard Error**	**T**	**|P| > t**
Nutrition Index	1.422	0.955	1.490	0.149
Indoor Pollution Index	0.002	0.753	0.000	0.998
Health Stock Index	0.392	0.271	1.450	0.150
Income	-0.139	0.235	-0.590	0.559
PM2.5	-0.135	0.654	-0.210	0.838
Mitigating Expenditure	0.141***	0.045	3.170	0.004

Dependent Variable: number of sick days
N=31, **R-square =0**

Table II: Descriptive Statistics

	Mean	Standard Deviation	Minimum	Maximum
No. of sick days	14.30	11.71	1.14	34.29
Mitigating Expenditure	1522	2560		10721
Nutrition Index	14.74	2.28	11.00	19.00
Indoor Pollution Index	10.85	1.99	6.75	14.38
Health Stock Index	1.13	2.24	0.00	7.00
Age	1	2	0	7
SO2	15.40	8.54	6.00	29.18
NO2	81.73	14.96	58.00	101.06
PM10	400.45	25.34	362.00	435.00
PM2.5	190.25	42.71	116.00	235.57
Income	256000	222428	50000	1200000

Table III: Units of Variables

S.No.	Variable	Unit
1.	Mitigating expenditures	Rs
2.	No. of sick days	Days
3.	Nutrition Index	NA
4.	Indoor pollution Index	NA
5.	Health stock Index	NA
7.	Age	Years
8.	SO2	$\mu g/m^3$
9.	NO2	$\mu g/m^3$
10.	PM10	$\mu g/m^3$
11.	PM2.5	$\mu g/m^3$
12.	Income	Rs.

Income holds a negative relationship with number of sick days. High income would imply lesser number of sick days.
PM2.5: an indicator of ambient pollution holds a negative relationship with sick days. One percent rise would lead to 0.135 percentage fall in number of sick days.
Mitigating Expenditure: Expenditure shows a positive relationship with number of sick days. A one percent rise in mitigating expenditure would lead to a 0.141 percent rise in sick days.

Nutrition Status
In the present study, data was collected on habits that affect health in general, including frequency of consumption of fruits, nuts, vegetables especially green leafy vegetables as also processed foods. It was found that majority of the households consumed green leafy vegetables (68%), other vegetables (78.0%), fruits (66.0%) and nuts (33.33%) on a daily basis. These foods are a rich source of protective micronutrients and antioxidants providing protection against damaging effects of air pollution. A high fruit and vegetable diet would lead to an improvement in micronutrient status (Vitamin C, E, B group Vitamins, and Carotenoids), corresponding with the lesser risk of asthma exacerbation [(8)]. Majority of the households (51.02%) reported consuming processed foods rarely/never, whereas 77.08% of the households were consuming some vegetable oils rich in PUFAs or olive oil. Several intervention studies in humans indicate that nutrients like antioxidants and omega-3 fatty acids may lessen the damage induced by air pollution. Antioxidant supplementation may be helpful in reducing air pollution-induced oxidative stress in the body, by both direct and indirect mechanisms.[(8)] In the present study, Vitamin A supplements were consumed by 12.5%, Vitamin C supplements by 19.6% and Vitamin E supplements by 10.7% of the subjects. Increased intake of antioxidants, as well as other anti-inflammatory nutrients, may attenuate air-pollution induced oxidative stress and inflammation in cardiovascular disease, asthma and other serious diseases.

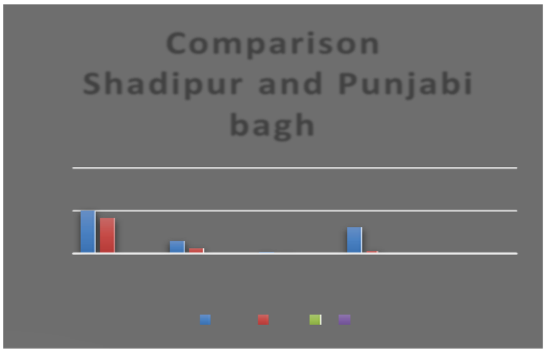

Figure VIII: Comparison of Shadipur and Janakpuri air pollution levels

NO_x, SO_x, CO and Ozone levels are high in Punjabi Bagh than Shadipur. One reason for this may be better developed road network in Punjabi Bagh which has resulted in a spurt of vehicles in that area.

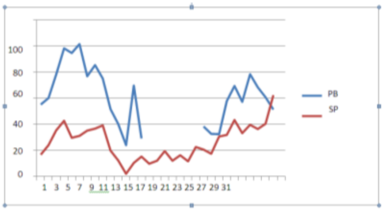

Figure IX: Ozone level in PB and SP

Higher ozone level in Punjabi Bagh indicates higher level of pollution in that area than Shadipur. Well-connected road network and 2 metro stations, relative closeness to airport induces increased traffic in that area[1].

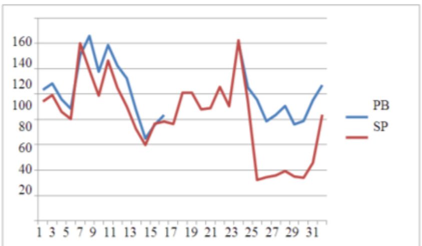

Figure X: NO_X level in Punjabi Bagh and Shadipur

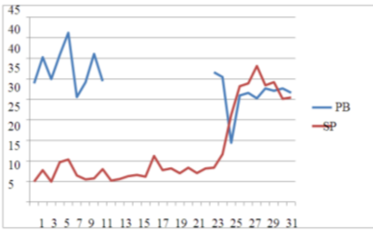

Figure XI: SO_x level in Punjabi Bagh and Shadipur

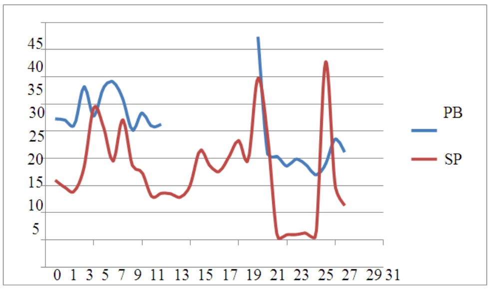

Figure XII: CO level in Punjabi Bagh and Shadipur

- Indoor Pollution Index is positively related to Mitigating Activities Expenditure (0.271) and positively related to Sick Days (0.083). As indoor pollution increases, the expenditure on mitigating activities also increases. Increase in indoor pollution also leads to an increase in number of sick days.
- Health Stock Index is positively related to Mitigating Activities Expenditure (0.572). It is also positively related to sick days (0.523). The more susceptible a person is to chronic diseases (indicated by Health Stock Index), the higher would be his expenditure on mitigating activities. Similarly, a positive relation between Health Stock Index and Sick Days indicates an increase in sick leaves due to bad health stock.
- Air Borne Disease Awareness Index is negatively related to Mitigating Activities Expenditure (-0.285). As awareness regarding air borne diseases increases, teed for mitigating expenditure reduces. Air Borne Disease Awareness Index is also negatively related to Sick Days (-0.390).
- Nutrition Index is positively related to Sick Days (0.328). Increase in Nutrition Index reflects a fall in natural and biological resistance to illness. This further enhances the expenditure on mitigating activities reflected by medical expenses.

DISCUSSION

- Punjabi Bagh suffers from high outdoor pollution showing high levels of NO_x, CO, SO_x and Ozone. This could be on account of better infrastructure, road connectivity and metro facility, making it more commercial with more vehicles on road.
- Powerhouse in Punjabi Bagh makes it more polluting location than Shadipur.
- The results indicate that health is positively related or gets affected by indoor pollution.
- The study also indicated that negative effect on health augments the expenditure on mitigating activities.
- More incidence of chronic diseases (Asthma, TB, Heart Diseases, Cancer etc. Indicated by health stock index would imply more expenditure on mitigating activities and increase in number of sick days.
- The results conform to the fact that a fall in natural and biological resistance to illness as indicated by nutrition index accounts for a higher expenditure on mitigating activities in form of medical expenses.
- No other study in any part of India has incorporated the nutrition variable as a measure of health conditions in the model. It becomes a different approach to see how nutrition along with pollution factor helps decide the health status of an individual.

CONCLUSIONS

This study provides an initial measure of health benefits from mitigation in air pollution from the current level to the national ambient air quality standard level in West Delhi. The study also finds that nutrition habits of individuals play a crucial role in reducing the number of sick days along with the indoor and outdoor pollution.

The study would recommend that government should reduce outdoor ambient pollution by introducing various renewable sources of energy which would reduce the levels of PM2.5, PM10 and NO2. The analysis also suggests that healthy food habits should be adopted by people so that they are less affected by the impact of air pollution and further reduce their expenses on medical treatment by minimizing the number of sick days. However, further studies are required for conclusive evidence in this regard.

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APPENDIX

Table IV: Correlation matrix

	Mitigating Activities Expenditure	Sick Days
Nutrition Index	-0.143	0.328
Indoor Pollution Index	0.271	0.083
Exercise Habits	-0.234	-0.213
Health Stock Index	0.572	0.523
Air Borne Disease Awareness Index	-0.285	-0.39