Socio-Economic Impact of Air Pollution on Dwellers of and around the Industrial Area in Tamilnadu, India

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Abstract

The study makes a solemn effort to review the factors affecting the environment and health, and the ways and means to improve the value of life of the people living in and around an industrial area. The purposes of the study include the assessment of the health effects of air pollution on the people who are residing around the industrial area, the approximation of the budgetary recurring expenditure towards treatment for health reparations of the sample families due to air pollution, the identification of the determinants of the inclination to pay and the readiness to accept of the sample families, and the recommendations suitable for policy measures to lessen environmental pollution. A two-tier sample design is the unique feature of the study. The first stage of sampling is the selection of the villages on the basis of distances from the industrial complex. The second stage of the sampling is the selection of families from the sample villages. An exploration survey of the area is undertaken with a view to gain insight into the economic conditions and health status of the people in the industrial area. Air pollution samples were collected from the industrial complex. The severity of air pollution has differed according to the nearness. Particularly, the children are affected severely than adults. The cost of illness is more in the zones which are nearer to the industries. Information regarding various other methods of pollution control, and preventive methods of air pollution from the chemical industries and the pollution effects on health and preventive measures should be collected by the Pollution Control Authorities so as to educate the industries' management and the surrounding village people.

Keywords: Air pollutants, Airborne diseases, Cost of illness, Contingent Valuation, Willingness to pay and to accept

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1. Introduction

1.1. Air Pollution and Health

Air pollution occurs when suspended particulate matter (spm) and noxious gases occur in the air. Smoke, ash and dust are major constituents of spm and sulphur and nitrogen based compounds. (SO_x, NO_x) and carbon monoxide and carbon dioxide are the main constituents of noxious fumes in the air. Among industrial activities, thermal power stations top the list of air polluters due to the high amount of discharge of smoke and ash. Chemical and fertilizer plants are also responsible for letting noxious substances in the air during production. The World Health Organisation (WHO) estimates that the maximum amount of spm in the air that does not affect human health is 90 microgrammes per cubic metre. In Calcutta the spm in the air is at least 410 microgrammes per cubic metre, which is the highest spm concentration in the country, India (WHO, 1996). Indoor air pollution is estimated to cause approximately 2 million premature deaths mostly in developing countries. Almost half of these deaths are due to pneumonia in children under 5 years of age. Urban outdoor air pollution is estimated to cause 1.3 million deaths worldwide per year. Those living in middle-income countries disproportionately experience this burden (WHO, 2011).

Air pollution causes diseases to the respiratory organs ranging from common cold, bronchitis, asthma, and lung cancer. The health effects vary greatly from person to person. High-risk groups such as the elderly, infants, pregnant women, and sufferers from chronic heart and lung diseases are more susceptible to air pollution. Children are at greater risk because they are generally more active outdoors and their lungs are still developing. Exposure to air pollution can cause both acute (short-term) and chronic (long-term) health effects (USEPA, 2013). Among hazardous gases carbon monoxide, which is an asphyxiant gas that interacts with the haemoglobin in the blood stream reduces its ability to carry oxygen. Sulphur dioxide is also a more serious pollutant. In low concentrations it causes temporary spasms in the smooth muscles of the bronchia. In higher concentrations it damages the cilia that protect the respiratory system causing cough, shortness of breath and spasms in the larynx. Oxides of Nitrogen cause pulmonary irritation and at higher concentrations may lead to pulmonary haemorrhage. Hydrogen sulphide has similar corrosive effects. Hydrocarbons emitted from auto exhausts from motor vehicles may cause lung cancer. Lead from the same source is a cumulative poison and may cause brain damage in children. Dust pollution causes silicosis.

Commonly known as ARI (Acute Respiratory Infections) kill more than 4 million people per year and are the leading causes of death among children under age 5. The range of infections includes pneumonia in its most serious form which accounts for more than 8 per cent of the global burden of disease. The risk factors of ARI are numerous and difficult to sort out. Caused by different viruses or bacteria, ARI is closely associated with poverty, overcrowding and unsanitary household conditions which lead to the transmission of disease, through cough or a sneeze or unwashed hands. Air borne diseases thrive in conditions of poverty, exploiting enclosed spaces, crowding, and poor hygienic conditions (WHO, 1996).

Chronic lung disease and pulmonale are the killers of adult Indian women. Low birth-weight and other adverse outcomes of pregnancy are also common as eye disease. It is also estimated that in India 40-60 per cent of pre-school children and 25-30 per cent of women in the reproductive age suffered from chronic lung diseases (Voluntary Health Association of India, 1992).

1.2. Air and Water Pollution and their Effects on the People in Tamil Nadu, India

Ambient air quality data reveals the status of air quality in selected cities in Tamil Nadu, India. The variations in air quality are measured by SO_2, NO_2, and suspended particulate matters contents in air. In Chennai (Metropolitan City) and Pondicherry (Union Territory), the SPM content in air remained above the national standard (SPM – 140 μg/cum) throughout the year. The annual average and annual maximum have been above the standard in these two cities. Regarding SO_2 and NO_2, the annual averages remained much below the standard in all the major cities in Tamil Nadu but the annual maximum variation in SO_2 in Chennai in the year 1994 was 398.4 μg/cum and in Pondicherry the maximum level was 228.7 μmg/cum in 1990. Likewise, the NO_2 content also remained below the standard in Coimbatore and Tuticorin and it is found out that annual maximum was below the national standard in these two cities (Agarwal, Anil, et.al. 1999).

Because of the variations in ambient air quality, the air pollution is found to be serious in Chennai, Tamil Nadu and Pondicherry, union territory of India. In Chennai, heavy cluster of industries and vehicles cause air pollution, and various industries located in Cuddalore (25 kms away from Pondicherry where

SIPCOT (State Industrial Promotion Corporation of Tamil Nadu) industrial complex is existing and Pondicherry cause air pollution.

2. Review of Literature

Many authors use air pollution effect on human health for their study. The research reviewed important evaluations in this study.

Rowe et. al, (1991) analysed the morbidity effect of air pollution in California by using the cost of illness approach. They considered the emergency room visits in calculating the cost of treatment for air pollution ailment.

Gopal Bhargava (1992) narrated the health hazards of the pollutants which include impairment of mental and physical function with symptoms of headaches and dizziness due to increased carbon monoxide contents. The oxides of nitrogen would play a vital role in the formation of photo-chemicals, causing eye irritation and breathing troubles. Nitrogen oxide would harm lungs and would increase the susceptibility to bacterial infections and plant damages. He also reported that there was evidence of higher mortality rates associated with continuous exposure to it.

A study made by Prusty and Rout (1992) found a correlation between air-borne diseases and environmental pollution. A disease co-efficient ranking was given for different hospitals in the area to ascertain the high intensity locations.

Varadarajan and Elangovan (1992) revealed that the atmospheric air would normally contain just 0.1 ppm of Carbon monoxide (Co). The toxic effect of Co on human beings and animals would rise from its reversible combination with haemoglobin in the blood. The combination of haemoglobin with Co lessens the oxygen-carrying capacity of the blood, so that less O_2 would be available to the body cells. It was through Co the cell function would be impaired by blocking oxidation in the blood circulation.

Agarwal and Kundanlal (1993) observed in their study that atmospheric change inflicted tremendous unfavorable effects in the form of air-borne diseases. Besides the risks from climatic natural disasters, like ozone depletion would cause skin-cancers. Solid and hazardous wastes also would cause diseases, affecting the health and would reduce human beings' normal physical living.

Bart Ostro (1994) analysed the effects of Sulfur dioxide (So_2) on the respiratory system. Several recent epidemiological studies indicated that changes in 24- hour average exposure to SO_2 might affect lung function, respiratory system and would result in the risk of mortality.

Marry Ellan Gordian et., al (1996) examined the association between average daily particulate matter of less than 10 µm in diameter ($p\mu_{10}$) and temperature with daily outpatient visits for respiratory diseases including asthma, bronchitis, in Anchorage in Alaska, due to air pollution caused by the industries. The results showed that an increase of 10 $\mu g/m_3$ in P_{M10} resulted in 3 to 6% increase in visits for asthma and 1 to 3% increase in visits for respiratory diseases.

Bart Ostro et., al (1998) examined how weather conditions and air pollution influence the risk of respiratory diseases among children in Santiago. Data on morbidity due to respiratory diseases among children less than 15 years of age had been collected from a group of public primary health clinics. The authors proved an association between clinic visits for respiratory illness and P_{M10} among the children aged 3 to 15 and for infants.

Maisonet, M., Correa, A, Misra, D, Jaakkola JJ. (2004) explained in their study that a review of the literature on the effects of ambient air pollution on fetal growth that effects of air pollution were apparent on preterm delivery (PTD) and intrauterine growth restriction (IUGR), but not on low birth weight (LBW). Most of the associations reported were rather small. The estimation of summary effects was not meaningful because of the heterogeneity of the effect estimates arising from differences in the measurements of outcome, exposure, and confounders and the small number of studies per outcome (four studies for PTD and six for IUGR). Current scientific knowledge on the impact of air pollution on fetal growth is still limited; thus, several issues should be examined further.

Radim J. Šrám et. al (2005) stated in their paper Ambient Air Pollution and Pregnancy Outcomes: A Review of the Literature that there is evidence implicating air pollution in adverse effects on different birth outcomes, but the strength of the evidence differs between outcomes. The evidence is sufficient to infer a causal relationship between particulate air pollution and respiratory deaths in the postneonatal period. For air pollution and birth weight the evidence suggests causality, but further studies are needed to confirm an effect and its size and to clarify the most vulnerable period of pregnancy and the role of different pollutants. Molecular epidemiologic studies suggest possible biologic mechanisms for the effect on birth weight, premature birth, and IUGR and support the view that the relation between pollution and these birth outcomes is genuine. In terms of exposure to specific pollutants, particulates seem the most important for infant deaths, and the effect on IUGR seems linked to polycyclic aromatic hydrocarbons, but the existing evidence does not allow precise identification of the different pollutants or the timing of exposure that can result in adverse pregnancy outcomes.

Wang et.al (2005) estimated sulfur dioxide (SO_2) and Total Suspended Particles (TSP) intake fractions for five cities of China in four main polluting industries: electric power generation industry, mineral (mostly cement) products industry, chemical process industry and metallurgical industry (mainly iron and steel smelting). Sensitivity analyses showed how the intake fractions were affected by the source and pollutant characteristics, the most important parameter being the size of the domain. However, the intake fraction estimates were robust enough to be useful for evaluating the local impacts on human health of primary SO_2 and TSP emissions.

Lopez et., al (2005) estimated health impacts due to air pollution from one of Mexico's largest power plants, Tuxpan, located on the eastern coast. The authors calculated the annual average concentrations of primary and secondary (sulfates and nitrates) particulate matter, by modeling representative periods during the year 2001. The authors found that emissions from the power plant resulted in annual average concentrations of 0.12 μg m^{-3} (min-maxi 0.00 – 1.43) for primary $\rho\mu_{2.5}$, 0.64 μg m^{-3} (0.01 – 2.84) for secondary $\rho M_{2.5}$ and 3.09 μg m^{-3} (0.01 – 41.54) for SO_2 in the 120 km x 120 km modeling domain. Emissions from the power plant could result in approximately 30 dealt annually after applying the appropriate value of statistical life for the region. The social cost of the power plant emissions were approximately 8 million US dollars in 2001. Secondary particulate matter contributed over 80% to the mortality impacts, most of which came from sulphate formation (73% total impacts), resulting from high SO_2 emissions.

Johansson et. al (2009). analysed PM_{10},NO,NO_2,CO in the Residents of Stockholm comparing with and without the City Centre Stockholm and observed reductions levels in city centre -10.0% for NOx, -7.6% for PM_{10} ;

Greater Stockholm: -5.3% for NOx , -3.8% for PM_{10}; per 100,000 people for Greater Stockholm over a 10-year period.

Goodman et., al (2009) observed the association of smoking bans at workplaces with health benefits for workers and the general population regarding respiratory and cardiovascular health.

K, Cambra, et.al (2011) studied Mortality in small geographical areas and proximity to air polluting industries in the Basque Country (Spain) that the association between proximity to air polluting industrial facilities and mortality in the Basque Country (Spain) in the 1996–2003 period. A cross-sectional ecological study applied with 1465 census sections (CS) as units of analysis with a mean population of 1257 inhabitants. Association of CS mortality with proximity of industries of the European Pollutant Emission Register was studied by type of industrial activity and adjusted for social deprivation. Two distance thresholds (1 km and 2 km) were used as proxies for exposure in a 'near versus far' analysis. Causes of mortality studied were: all causes; tracheal, bronchial, and lung cancer; haematological tumours; ischaemic heart disease; cerebrovascular diseases; chronic diseases of the lower respiratory tract; and breast cancer (in women). Poisson's generalised linear mixed models (GLMM) with two random effects (heterogeneity and structured spatial variability) were used in a fully Bayesian environment. Men living in sections within 1 km from energy production industries had greater mortality from tracheal, bronchial, and lung cancer [$CI_{90\%}$ 6% to 53%] as compared with people living further. Women had greater mortality from ischaemic heart disease [$CI_{90\%}$ 1% to 17%] and respiratory illness [$CI_{90\%}$ 1% to 24%] within 2 kms from metal-processing industries. On the contrary, within the 1 km buffer from mineral industries, mortality was lower for all causes [$CI_{90\%}$ −20% to −6%] and for ischaemic heart disease [$CI_{90\%}$ −40% to −10%] in women, and from respiratory diseases in men [$CI_{90\%}$ −39% to −4%], while it was greater for breast cancer in women [$CI_{90\%}$ 2% to 28%] within the 2 km buffer. Analysis of mortality by census sections is a helpful exploratory tool for investigating environmental risk factors and directing actions to sites and risk factors with a greater impact on health. Further epidemiological and environmental investigations around metal-processing and energy-producing plants are required.

Cizao Ren, et.al (2011) analyzed that ambient temperature and air pollution are associated with cardiovascular disease and that they may interact to affect cardiovascular events. However, few epidemiologic studies have examined mechanisms through which ambient temperature may influence cardiovascular function. The authors examined whether temperature was associated with heart rate variability (HRV) in a Boston, Massachusetts, study population and whether such associations were modified by ambient air pollution concentrations. The population was a cohort of 694 older men examined between 2000 and 2008. The authors fitted a mixed model to examine associations between temperature and air pollution and their interactions with repeated HRV measurements, adjusting for covariates selected a priori on the basis of their previous studies. Results showed that higher ambient temperature was associated with decreases in HRV measures (standard deviation of normal-to-normal intervals, low-frequency power, and high-frequency power) during the warm season but not during the cold season. These warm-season associations were significantly greater when ambient ozone levels were higher (>22.3 ppb) but did not differ according to levels of ambient fine (≤2.5 μm) particulate matter. The authors conclude that temperature and ozone, exposures to both of which are expected to increase with climate change, might act together to worsen cardiovascular health and/or precipitate cardiovascular events via autonomic nervous system dysfunction.

Giuliano Polichetti and Federico (2012) reviewed that the sources of ambient air pollution are various (vehicle emissions, industrial and domestic emissions, forest fires, cigarette smoke, natural trees, and climate variations) such as the pollutants that are a mixture of gaseous (CO, NOx, SO2, O3), diesel exhaust particles (DEPs), particulate matter (PM10, PM2.5, ultrafine particulates) and polycyclic aromatic hydrocarbons (PAHs). The pollution is ubiquitarian especially in the Western world even if its composition and concentration levels are extremely different; therefore the study of its possible effects on the public health assumes great importance.

Nicky Pieters, et.al (2012) analyzed in their study on the association between short-term exposure to ambient air pollution and heart rate variability (HRV) and suggest that particulate matter (PM) exposure is associated with reductions in measures of HRV, but there is heterogeneity in the nature and magnitude of this association between studies. The authors performed a meta-analysis to determine how consistent this association is. Of the epidemiologic studies reviewed, 29 provided sufficient details to be considered. The meta-analysis included 18667 subjects recruited from the population in surveys, studies from patient groups, and from occupationally exposed groups. The authors computed pooled estimates from a random-effects model. In the combined studies, an increase of 10 $\mu g/m^3$ in $PM_{2.5}$ was associated with significant reductions in the time-domain measurements, including low frequency (−1.66%, 95% CI −2.58% to −0.74%) and high frequency (−2.44%, 95% CI −3.76% to −1.12%) and in frequency-domain measurements. Funnel plots suggested that no publication bias was present and a sensitivity analysis confirmed the robustness of our combined estimates. The meta-analysis supports an inverse relationship between HRV, a marker for a worse cardiovascular prognosis, and particulate air pollution.

Reviewing the various methods of measuring the health effects of pollution (Cropper et al, 1989), the cost of illness approach and contingent valuation (Abdalla et. al 1992, Misra, 2002) are chosen to measure the air pollution in the study area viz., Gujarat, India.

Based on the above reviews by the authors, the research constructed setting of the problems, analysis part of the study and result and discussions.

3. Statement of the Problem

Exposures to chemical agents from the industries in general and chemical industries in particular in the environment (air, water and soil) have resulted in numerous adverse effects on human beings.

Some pollutants of particular concerns are airborne substances primarily suspended particles, sulfurdioxides, nitrogen oxides and carbon monoxide that are emitted from the industries in industrial complexes. The surrounding people in the industrial complexes are regularly exposed to potential harmful emissions which are confirmed to contribute to airborne diseases such as cold, respiratory problem, flu, bronchitis, and asthma.

The above stated facts reveal the exposure of human beings to chemically induced pollutants resulting in various types of health hazards and economic losses. Considering the above stated facts, the researcher has taken a micro level study on the economic impact of pollution choosing SIPCOT (State Industrial Promotion Corporation of Tamilnadu) industrial area, Cuddalore in Tamilnadu, India.

4. Research Design

4.1. Objectives

The study is conducted with special reference to the SIPCOT complex in Cuddalore district of Tamil Nadu, India. The overall objective of the study is to probe into the impact of air pollution in the study area. In this context the study makes an earnest attempt to probe into the factors affecting the environment and health and the ways and means to improve the quality of life of the people living in and around SIPCOT area, Cuddalore. The specific objectives of the study are:

1. To access the amount of air pollution in the SIPCOT area, Cuddalore.
2. To estimate the financial cost of health damages of the sample households due to air pollution.
3. To identify the determinants of the willingness to pay and the willingness to accept of the sample households.
4. To suggest suitable policy measures to reduce environmental pollution.

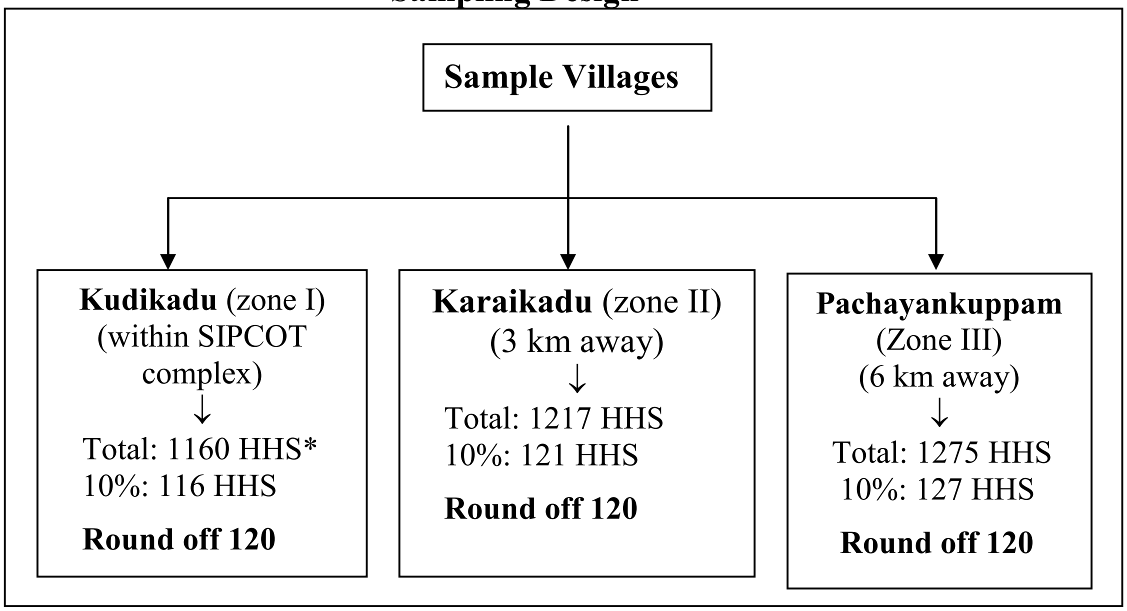
4.2. The Survey Design

4.2.1. Selection of the Villages and Samples

A two-tier sample design is the unique feature of the study. The first stage of sampling is the selection of the villages on the basis of distances from the SIPCOT industrial complex. The first village is located within the complex of SIPCOT. The second one is located 3 kms away from the SIPCOT, and the last one is located at 6 kms from the SIPCOT complex. Kudikadu, Karaikadu and Pachayankuppam are the selected villages and these villages are named as zone I, zone II, and zone III respectively.

The second stage of the sampling is the selection of households from the sample villages. In order to obtain a symmetrically representative sampling, the sample of 10 per cent households from each village is selected. Further, the samples are rounded off to 120 in each village. Hence the sample size is 360 households.

Sampling Design



*Households

4.2.2. Method of Enquiry

A reconnaissance survey of the area is undertaken with a view to gain insight into the economic conditions and health status of the people in the SIPCOT area. Additional information is gathered from Federation of Consumer Organization of Tamil Nadu and Pondicherry (FEDCOT), Non-government Organizations (NGOs), Doctors, and Contractors Association and observations made during the preliminary survey. The selected respondents are contacted in person and inquired using the pre-tested schedule. The objectives and importance of the study are explained to the respondents briefly to elicit their co-operation. All respondents do not maintain any proper records regarding the occurrence of air borne diseases, expenditures on medicine and duration of illness. But they are able to recapitulate and furnish the information. But cross checks are found necessary to minimize the errors due to recall bias.

5. Limitations

This study is confined to the analysis of air pollution only on people who are living in around the villages of the SIPCOT complex and it does not focus on the occupational health hazards of SIPCOT industrial workers because the information regarding the health impact could not be properly elicited from the industrial workers.

6. Results and Discussion

6.1. Air Quality in the SIPCOT Area, Cuddalore

This section presents the extent of air pollution in SIPCOT area. The atmosphere readily absorbs varied pollutants released by the industries in the production process. Any excessive release of air pollutants in the atmosphere by the industrial activities disturbs the dynamic equilibrium in the atmosphere and thereby affecting human beings and environment. Due to the polluted air, many air borne diseases affect the human beings. A report of air quality is presented by the Cuddalore District Consumer Organisation (CDCO), Federation of Consumer Organization - Tamil Nadu and Pondicherry (FEDCOT), Global Community Monitor (GCM) is the Other Media organizations who measured the air quality in SIPCOT industrial area. The report indicated the prevalence of air pollution and also revealed the extent of chemical pollutants in SIPCOT region. Table 1 shows the extent of air pollutants in SIPCOT complex. Among the pollutants, Toluence, Carbon Tetrachloride, 1,2-Dichlorothane, and Acrolein are found in heavy concentration. The permissible limits of all these pollutants fixed by Environmental Protection Agency (USA) are as follows:

Hydrogen Sulphite	-	1.00 μg / m^3
Methylmercaptan	-	2.1 μg / m^3
Methylene Chloride	-	4.09 μg / m^3
Trichloroethane	-	1.10 μg / m^3
Toluence	-	4.00 μg / m^3
Chloroform	-	0.084 μg / m^3
Carbon tetrachloride	-	0.13 μg/m^3
1,2-Dichlorothane	-	0.074 μg / m^3
Benzene	-	0.25 μg / m^3
Acrolein	-	0.021 μg/m^3
n-Hexane	-	210 μg / m^3

1,2 Dichlorothene – 1700 μg/m^3, Carbon Tetrachloride – 1500 μg / m^3 toluence – 700 μg/m^3 and acrolein – 6.5 μg/m^3. Other than these pollutants, methylmercaptan and methylchloride also exceeded their limits from permissible limits of 2.1 μg/m^3 and 4.09 μg/m^3 to 11.6 μg/m^3 and 360 μg/m^3 respectively. Hydrogen sulphide, trichlorothene, chloroform, benzene and n-Hexane too exceeded the permissible limits. Hydrogen sulphide exceeded from 1.00 μg/m^3 to 13.1 μg/m^3 while chloroform and benzene exceeded to 80 μg/m^3 and 27 μg/m^3 respectively. n-Hexane exceeded to 420 μg/m^3. These are the chemicals which pollute the SIPCOT environment. The air pollution effect is assessed from the residents by an opinion survey. The results of the survey are ranked and presented in Table 2.

6.2. Ranking for the Varied Effects of Air Pollution

The pollutant air has resulted in various types of morbidity and production loss of crops and plants and Table 2 explains the ranking of the effects of air pollution. Due to air pollution, the health of the people is highly affected in various ways, as reduced visibility and increased cost of health care. The pollution has also resulted in the fall in production of crops and plants. In the study region, all sample respondents have given rank – I (average mean score 4.00) for the varied health effects. The residents have given ranks II and III for the effects on crops and plants and for the health care expenditure respectively. In zone III, the respondents have given rank II (average mean score 3.00) for the effects on crops and plants. It could be observed from the table that effects of pollution on human health are felt to be more severe than those on crops, plants and livestock.

6.3. Airborne Diseases in Sample Households

In the study region, the respondents have reported that the air contains dust particles and is very dirty with bad odour. The polluted air brings various health damages to human beings including mortality and various types of morbidity. The airborne diseases prevalent in the sample zones are cold, respiratory problems, flu, bronchitis and asthma. The diseases incurred due to air pollution are recorded within three months (90 days) as per advice of medical counselor. It includes all illnesses that the respondents have undergone during the period. No mortality is found in this period. Hence the analysis is restricted to morbidity only.

The various airborne diseases that the sample households have undergone are given in Table 3. Among the diseases, cold constitutes the highest percentage of all the airborne diseases. Respiratory problems are found to be higher than bronchitis. Flu and asthma are found to be in the next level. In zone I, 71 per cent of female children and 63.9 per cent of male children are affected by cold. 38.4 per cent of adult male and 35.5 per cent of adult female are also affected by cold. Children are easily affected by cold than the adult population. In zone II, 48.2 per cent of male children and 43.2 per cent of female children are affected by cold. Adult males and females are affected by cold form the percentages of 27.3 and 22.4 respectively. In zone III, 37.9 per cent of male children are affected by cold and the percentage is more than female children (35.6%) whereas 16.2 per cent of adult females and 12.6 per cent of adult males are affected by cold.

A review of respiratory problems of households reveal that 46.4per cent of male children and 35.1 per cent of female children in zone I are affected by respiratory problems, whereas 24.2 per cent of adult males and 29.7 per cent of adult females are affected by the respiratory problem in the same zone. In zone II,35.9 per cent of female children have respiratory problems and 29.7 per cent of male children are affected by the same. In case of adults, 17.7 per cent and 18.8 per cent of males and females are affected in zone II. In zone III, the affected sample is low when compared with other zones. That is, 15.2 per cent of male children and 16.4per cent of female children have respiratory problems while adult males and females form the percentages of 11.3 and 11.5 respectively.

Flu caused by air pollution is found at lower rate than cold, respiratory problems and bronchitis. In zone I, 14.5 per cent of female children are affected by flu, 9.9 per cent and 9.5 per cent of adult males and females are affected by flu respectively. In zone II, the flu infection rate is less due to the location, which is away from the SIPCOT complex. That is, 11.1 per cent of male children, 7.3 per cent of female children, 6.4 per cent of adult males and 3.8 per cent of adult females are affected. Flu rate is lower in zone III than that of zone I and II. In
In zone III, 8.2 per cent of female children, 3.8 per cent of male children, 4.1 per cent of adult males and 4.7 per cent of adult females are affected by flu respectively.

Bronchitis, which is due to the severity of cold, is found to be at a higher rate than flu. In zone I, 31.9 per cent of female and 22.7 per cent of male children are affected, whereas 19 per cent of adult males and 15.3 per cent of adult females are affected by bronchitis. In zone II, affected male and female children form the percentages of 16.1 and 11.3 respectively, and 9.6 per cent of adult males and 8.9 per cent of adult females are also affected. In zone III, 13.9 per cent of male and 9.6 per cent of female children suffer due to bronchitis while 5 per cent of male and 4.7 per cent of female adults have the problem of Bronchitis.

Asthma is recorded at lower level as compared with other diseases in the study zones. In zone III, the respondents are free from asthma. In zone I, 7 adult males (3.3%) and 5 adult females (2.7%) are affected by asthma whereas 5 females (2.6%) and 2 adult males (0.9%) are found to be suffering in zone II. Thus, the severity of air borne disease is high in zone I rather than zones II and III. As zone I is nearby the industrial area, the pollution significantly affected zone I and it is found that the severity differs according to the nearness of zones to SIPCOT industries. Particularly, the children are affected more severely than adults. Children are considered as the potential human resource of a nation. But, pollution in the study region has affected the children considerably which puts the future development of the country in question.

The incidence of airborne diseases is analyzed and presented under the following headings: (1) Zone – wise incidence of airborne diseases, (2) Age – wise incidence of airborne diseases, (3) Incidence of airborne diseases on male adults and male children in the sample and (4) Incidence of airborne diseases on female adults and female children in the sample. For zone – wise incidence of airborne diseases on children, adults and on total sample households, χ^2 analysis is applied to see the association between residential locations (zones) and incidence of diseases. For age wise incidence and gender wise incidence 'Z' statistics is applied to see which age group is significantly affected and also to see whether children (male and female) or adults (male and female) are significantly affected by airborne diseases.

6.4. Zone-wise Incidence of Airborne Diseases in the SIPCOT Area

Incidence of airborne diseases varies according to the nearness of the zones to SIPCOT complex. If the zone is away from the SIPCOT, then the incidence of disease is at lower level. Table 4 explains the incidence of diseases on children. In zones I, 86.1 per cent of children are affected while 71.6 per cent and 59.2 per cent of children in the zones II and III are affected respectively. Of the total children, 72.8 per cent are affected by the airborne diseases. χ^2 value calculated shows the association between incidence of airborne diseases and zones. It is 29.16, which is higher than the table value of 9.210 and is significant at 1 per cent level. This result shows that there is significant variation between zones and the incidence of airborne diseases on children.

Table 5 portrays the incidence of airborne diseases on adults. In zone I, 57.6 per cent of the adult populations are affected while 32.3 per cent of sample in zone II and 21.5 per cent of sample in zone III are affected. Among the total, 1255 adults, 375 persons (30.5%) are affected. χ^2 is calculated to see the association between zones and incidence of diseases. χ^2 value is 18.00 and significant at 1.8 per cent level. It could be also observed from this that the distance of the location (zone) from SIPCOT industries influences the incidence of the airborne diseases.

Table 6 explains the incidence of airborne diseases on the total households. Among the total 1,677 members, the infected are 703 persons (41.9%). In zone I, 52.1 per cent of the members are affected while in zones II and III, 41.9 per cent and 31.7 per cent are affected respectively. Calculated χ^2 value is 36.59 which is significant at 1 per cent level. It also expressed that incidence of airborne diseases is associated with the zones.

6.5. Age-Wise Incidence of Airborne Diseases in the SIPCOT Area

Incidence of disease varies according to the age group of the sample population. Considering this, the study has classified the affected children and adults according to different age groups. ‘Z’ test is applied to see the variation in the incidence of airborne diseases between children and adults. (See Table 7). In zone I, out of the total 166 children, 143 are affected by airborne diseases while 152 adults are affected out of a total of 400 adults. Thus, it could be noticed that the infection of airborne diseases is higher among the children rather than adults. Besides, a similar trend could be seen in cases of zones II and III. However, the severity of disease is high among the children of zone I where the ‘Z’ calculated value is 11.30 which is significant at 1 per cent level. Besides, in zones II and III, ‘Z’ values are significant at 5 per cent level and there is meager difference compared to that of zone I. In the study region, the incidence of disease is greater among children than adults and the ‘Z’ value is significant at 1 per cent level. Hence, it could be inferred from this analysis, that age has influence over the occurrence of diseases.

Gender wise incidence of diseases is analysed and presented in Tables 8 and 9. Table 10 gives the details of male children and male adults affected by airborne diseases. In zone I, of the total of 97 male children, 78 are affected by airborne diseases while 83 male adults are affected out of the total of 211 adults. Likewise, in zones II and III, the severity of diseases is more among the children rather than on adults. The 'Z' test results show that children are more significantly affected than adults in all the zones. The zonal level test shows that the disease occurrence is more among male children and the 'Z' test value is significant at 1 per cent level. Thus, the incidence of diseases is more on male children in all the zones.

The incidence of diseases on female children and female adults is presented in Table 9. In the case of feminine gender also, female children are affected more than female adults. The 'Z' value shows that female children are more significantly affected than female adults. Thus, the incidence of disease is more on children rather than on adults.

6.6. Average Cost of Airborne Diseases

Pollution of the SIPCOT has affected the human health and has made the people to incur more medical expenditure. The costs incurred by the sample households have been classified as direct and indirect costs. In direct costs, doctor fees, medicinal expenses, diagnostic cost (Fees on clinical test) are taken into account. Travel cost to the dispensaries and loss of income are brought under indirect costs (Table 10).

The average direct costs are in terms of Indian Rupees (*INR*) 1,048 and *INR* 981 are the indirect costs per month incurred by the sample households. In direct costs, more expenses are made on medicine (*INR* 1074), doctor fees of *INR* 948 and *INR* 792 for diagnosis are spent by the sample households. Under the indirect costs, loss of income is *INR* 1,098 while *INR* 830 is the travel expense made by the sample households. They also incurred more expenditure on medicines while loss of income due to diseases is higher than other indirect cost.

Of the various zones, the sample households in zone I have spent *INR* 517 on direct costs and *INR* 477 on indirect costs. These are more than those of zones II and III. In direct costs, medicinal expenses is more in all the zones while in indirect costs, loss of income is found to be higher in all the zones.

Among the various diseases classified, majority of the sample households spent more for cold and respiratory diseases. Thus, the infection of cold and respiratory problem is more in the study region and this was due to the polluted air. Particularly in zone I, the infection is high due to the nearness, which affects their health severely.

6.7. Estimates of Airborne Diseases

The study probes further into the determinants of the cost of air borne diseases (Table 11). The determinant variables are (1) Zones (2) Income (3) Number of health affected persons (4) Number of days of illness, and (5) Proportion of severely affected persons. For analyzing this, MLRM is used. Multiple Linear Regression model $Y = a_1 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + ... +u$ estimators b_s provide the marginal effect of endogenous variable (Y) with respect to the corresponding predictor variables (x). Here, endogenous variable (Y) is cost of airborne diseases. Predictor variables (x) are as follows: (1) Zone (x_1), (2) Income (x_2), (3) Number of disease affected persons (x_3), (4) Number of days of illness (x_4), and proportion of severely affected person (x_5). The results show that zone and income significantly influence the cost at 5 per cent level and the values are 0.90 and 0.089 respectively. Number of health affected persons, number of days of illness and proportion of severely affected persons are also influencing the cost since these estimators' values are significant at 1 per cent level and the values are 0.585, 0.235 and 0.450 respectively.

6.8. Contingent Valuation

According to the environmental analysts, for measuring the environmental quality, there is no direct and reliable method. However, the environmentalists suggest contingent valuation method for assessing the values for environmental good. Contingent valuation methods are used when markets for public goods do not exist. The valuation task here is to determine how much importance people show for the environmental good. This is computed by asking how much the people are Willing To Pay (WTP) for an environmental benefit or how much they are willing to give for improving the environmental quality. This method is also used in terms of how much people are Willing To Accept (WTA) as a compensation for the poor environment.

6.8.1. Willingness to Pay for Better Air Quality

In the study region, the people are willing to pay for improving air quality. The WTP details are given in Table 12. The willingness to pay bids is expressed in monetary terms of Indian Rupees (*INR*) viz., *INR* 25, *INR* 50, *INR* 75 and *INR* 100 per month by each resident in the polluted area. In total, 68.3 per cent of the sample respondents are not willing to pay whereas 28.3 per cent of sample respondents are ready to pay *INR* 25 and only 3.4 per cent of the sample respondents are willing to pay *INR* 50. In zone I, 58.3 per cent of sample respondents is not willing to pay for improving air quality and in zone II and zone III, 70.8 per cent and 75.8 per cent are not willing to pay respectively. Of the sample respondents, 31.7 per cent are willing to pay *INR* 25 in zone I while 29.2 per cent and 24.2 per cent are willing to pay the same amount in zones II and zone III respectively. But, only 10 per cent of the respondents in zone I are ready to pay *INR* 50 for reducing the air pollution while none in zones II and III is ready to pay *INR* 50. In case of *INR* 75 and 100, nobody is prepared to give those amounts as their economic conditions are poor. Comparatively, the sample households in zone I are ready to pay more for the improvement of air quality. From this, it could be inferred that zone I is highly affected and this has prompted the people to come forward and to pay more for the better environmental quality.

6.8.2. Willingness to Accept the Prevalence of Air Pollution

Table 13 gives the details of willingness to accept for the prevalence of air pollution and all the respondents are willing to accept money as compensation for the tolerance of air pollution. In zone I, 88.3 per cent of the samples are willing to accept *INR* 100 for polluted air whereas 10 per cent and 1.7 per cent are willing to accept *INR* 75 and *INR* 50 respectively. In zone II, 84.2 per cent of the sample accepts *INR* 100 and 15.8 per cent of sample accepts *INR* 75 respectively. In zone III, 70.8 per cent of sample accepts *INR* 100 and 29.2 per cent of sample accepts *INR* 50 for the polluted air. Thus, the sample households are ready to accept some amount for the polluted air. However, the people suffer due to air borne diseases and they have to spend more amounts for overcoming this problem. So, compensation cannot be a solution for solving the problem.

6.8.3. Determinants of WTP and WTA

The previous discussion presented the WTP and WTA details of the sample households. This section probes the explanatory variables that influence the WTP and WTA of the sample household. The factors influencing the WTP and WTA are analysed by fitting a Multiple Linear Regression Model. Separately for WTP and WTA $Y = a_1 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + ... +u$, Y is willingness to pay and willingness to accept. Predictor variables are as follows : (1) Age (x_1), (2) Education (x_2), (3) Loss of Income (x_3), (4) Family size (x_4), (5) Per capita income (x_5), (6) Households health cost (x_6), (7) Zone II (x_7) and (8) Zone III (x_8). Table 14 gives the results of the above approach to find the influence on WTP and WTA by various explanatory variables, viz., age, education, loss of income of the families, family size, per capita income, health care expenditure and zones.

Of the given explanatory variables, zone III influenced WTP and WTA at 1 per cent level of significance which shows that the respondents in zone III are ready to pay and accept for the environmental quality. In case of education, family size and per capita income the WTP is influence significantly at 1 per cent level, by these variables and WTA is also influenced significantly at 5 per cent level by these variables. Thus, this shows that the sample households are ready to pay and accept for improving the environmental quality. Besides, the age has significant (1%) influence over WTA rather than WTP. This is because the aged people are much interested to accept compensation for the environment. The household health care expenditure also influenced significantly the WTP for the environmental quality, which is significant at 1 per cent level whereas the same response was not in the case of WTA. Hence, it could be observed from the above discussion that the WTP is significantly influenced by education, family size, per capita income, health care cost and zones whereas in case of WTA, the significance of all the predictor variables is not found.

7. Conclusion and Policy Suggestions

7.1 Conclusion

The analysis of the air pollution problems of the sample households in the SIPCOT zones reveals the following results:

Air Pollution in the SIPCOT Area: The breathing air is severely polluted in SIPCOT area by the prevalence of various air pollutants. Toluence, Carbon Tetrachloride, 1,2-Dichlorothane, Acrolein, Methymercaptan, Methylchloride, Hydrogen Sulphide, Trichlorothem, Chloroform, Benzene, and n-Hexane have exceeded the EPA permissible limits. These are the chemical pollutants which have polluted the SIPCOT environment. Due to the polluted air in the SIPCOT area various airborne diseases are prevalent.

Ranking Analysis: Ranking for air quality is done based on the average mean score values assigned to various pollution problems. The ranks are assigned according to the average mean score values. For the highest average mean score values higher ranks are assigned.

Ranking for Varied Effects of Air Pollution: In the SIPCOT region, all sample respondents have given rank – I (4.00) for varied health effects due to pollution. In zone I, the people have given rank II and III for the effects on crops and plants and rank I for the health care expenditures respectively. In zone III, also the respondents have given rank II (3.00) for the effects on crops and plants while rank I for the effects on health. It could be observed from the ranking analysis that effects of pollution on human health are felt to be severe by the respondents.

Airborne Diseases of Sample Households: The severity of airborne diseases is high in zone I rather than in zones II and III. As zone I is nearby the industrial area, the pollution has significantly affected the health of the people in zone I and it is also found that the severity has differed according to the nearness. Particularly, the children are affected more severely than adults.

Zone-wise Incidence of Airborne Diseases in the SIPCOT Area: Among the 1677 sample respondents, the airborne diseases affected persons were 703 which formed 41.9 per cent. In zone I, 52.1 per cent of the sample is affected while in zone II and zone III, 41.9 per cent and 31.7 per cent are affected respectively. It is also seen that the incidence of airborne diseases varies between the zones.

Age-wise Incidence of Airborne Disease in the SIPCOT Area: In zone I, of the total 166 children, 143 were affected by airborne disease while 152 adults were affected out of the total of 400 adults. In zone II, of the total of 134 children, 96 were affected by airborne disease whereas 133 adults were affected out of the total of 412. In zone III, 90 children were affected out of the total of 152 and 89 adults were affected of the total 413. Thus, the severity of diseases is more on children rather than on adults.

Average Cost of Airborne Diseases: Among the various diseases classified, majority of the households spent more on cold and respiratory problems due to the chemical pollutants which polluted the breathing air. Among the sample households, the sample population in zone I has spent *INR* 157 on direct cost and

INR 477 on indirect cost per month in zone I. The amount spend is more than that of zones II and III.

Estimates of Airborne Diseases: In the MLRM analysis, the results show that zone and income significantly influenced the cost at 5 per cent level and the values are 0.90 and 0.089 respectively. Number of diseases affected persons, number of days of illness, and proportion of severely affected persons have influenced the cost and the regression estimates are significant at 1 per cent level and the values of the estimators are 0.585, 0.235 and 0.450 respectively.

Willingness to Pay for Preventing Air Pollution: Of the sample respondents, 31.7 per cent were willing to pay Indian Rupees (*INR*). 25 in zone I while 29.2 per cent and 24.2 per cent were willing to pay the same amount in zones II and III respectively. Only 10 per cent of the respondents in zone I were ready to pay *INR* 50 for preventing the air pollution while nobody was ready to pay in zones II and III. In case of bids of *INR* 75 and 100, none are registered. As their economic conditions are poor, the willingness to pay bids have meager responses among the sample respondents. Comparatively, the population in zone I was ready to pay more for the improvement of air quality. From this, it could be observed that zone I was highly affected and this has made the people to come forward and to pay more for the environmental quality.

Willingness to Accept for Air Pollution: In zone I, 88.3 per cent of the samples were willing to accept *INR* 100 for tolerating the effects of polluted air whereas 10 per cent and 1.7 per cent are willing to accept lesser compensations of *INR* 75 and *INR* 50 respectively. In zone II, 84.2 per cent of sample has accepted *INR* 100 and 15.8 per cent of sample has accepted *INR* 75 as compensation. In zone III, 70.8 per cent of samples have accepted *INR* 100 and 29.2 per cent of the sample has accepted *INR* 50 for the tolerance of polluted air. Thus, the sample households are ready to accept some amount for the polluted air. From WTP and WTA bids, it could be inferred that the people are even ready to tolerate the pollution but they are not ready to share any burden and they expected that pollution should be controlled by the government and industrial authorities.

Estimates of WTP and WTA: Of the given explanatory variables, location influences WTP and WTA at 1 per cent level of significance which shows that the nearby residents to SIPCOT industries are ready to pay and accept for the environmental quality. In case of education, family size and per capita income, the WTP is influenced significantly at 1 per cent level by these variables and WTA is also influenced significantly at 5 per cent level by these variables. Thus, the sample respondents are ready to pay and accept for environmental quality. Besides, the age has significant (1%) influence over WTA rather than WTP. This is because the aged people are much interested to accept compensation for the environment.

7.2 Policy Suggestions

The following are the important suggestions that flow directly from the analytical part of the study. The suggestions are addresses to all policymakers in pollution control activities in the SIPCOT area, namely the government, Central Pollution Control Board (CPCB), Pollution Control Board (PCB) of the District and Non-Government Organizations (NGOs). They are meant to help them deal with the problem of industrial pollution. There is no real solution to deal with pollution after it is caused. The real solution is pollution prevention.

1. The incidence of cold, respiratory, flu and bronchitis is more in the study area on children. Hence the vulnerable section affected by pollution are children. Therefore children should be given special medical care and measures should be designed to control the prevalence of these diseases in the study area.
2. Industrial authorities are expected to give compensation to the people who are severely affected by the air pollution.
3. In the SIPCOT, there is no any filter to exhaust the polluted air. It is directly exhausted through the chimney into the air and the polluted air is directly breathed by the surrounding people which is the cause of the airborne diseases. The Pollution Control Board (PCB) authority should check and continuously monitor the industry to filter the polluted air. The task can be effectively executed by mobilizing the contribution of the residents who are willing to pay for environmental protection.

4. Information regarding various other methods of control, and prevention of air pollution from the chemical industries and the pollution effects on health should be collected by the PCB. This information should be disseminated to the SIPCOT management, surrounding village people, NGOs who are working for the reduction of industrial pollution and the doctors who are giving medical treatment for the pollution affected people.
5. Steps should be taken to promote and develop the manufacture of low cost appliances and devices for safety environmental protection in the SIPCOT industries.

Appendix:

Table 1. Air Pollution in the SIPCOT Complex

Sl. No.	Air Pollution Chemicals	EPA*level $\mu g/m^3$	SIPCOT $\mu g / m^3$
1.	Hydrogen sulphide	1.00	13.1
2.	Methylmercaptan	2.1	11.6
3.	Methylene Chloride	4.09	360
4.	Trichloroethane	1.10	140
5.	Toluence	400	700
6.	Chloroform	0.084	80
7.	Carbon Tetro Chloride	0.13	1500
8.	1, 2 – Dichlorothane	0.074	1700
9.	Benzene	0.25	27
10.	Acrolein	0.021	6.5
11.	n-Hexane	210	4200

Source: Report of CDCO, FEDCOT, GCM, and the Other Media.
* EPA – Environmental Protection Agency

Table 2. Ranking for Consequences of Air Pollution

Sl. No.	Rank	Zone - I	Zone - II	Zone - III
1.	Reduced Visibility	0 (0.0)	0 (0.0)	0 (0.0)
2.	Health Effects	4.00 (I)	4.00 (I)	4.00 (I)
3.	Increased Medical Expenses	0.13 (III)	1.21 (III)	0 (0.0)
4.	Effects on Crops and Plants	2.69 (II)	1.58 (II)	3.00 (II)

Source: Computed
Note: Figures in parentheses denote rank

Table 3. Airborne Diseases Wise Distribution of Sample Household members in SIPCOT area

Sl. No.	Airborne Diseases	Zone – I					Zone – II					Zone – III				
		Child Male (n = 97)	Child Female (n = 69)	Adult Male (n = 211)	Adult Female (n = 189)	Total (n=566)	Child Male (n = 81)	Child Female (n = 53)	Adult Male (n = 220)	Adult Female (n = 192)	Total (n=546)	Child Male (n = 79)	Child Female (n = 73)	Adult Male (n = 222)	Adult Female (n = 191)	Total (n=565)
1.	Cold	62 (63.9)	49 (71.0)	81 (38.4)	67 (35.5)	259 (45.8)	39 (48.2)	23 (43.4)	60 (27.3)	43 (22.4)	165 (30.2)	30 (37.9)	26 (35.6)	28 (12.6)	31 (16.2)	115 (20.4)
2.	Respiratory Problem	34 (35.1)	32 (46.4)	51 (24.2)	56 (29.7)	173 (30.6)	24 (29.7)	19 (35.9)	39 (17.7)	36 (18.8)	118 (25.6)	12 (15.2)	12 (16.4)	25 (11.3)	22 (11.5)	71 (12.6)
3.	Flu	8 (8.3)	10 (14.5)	21 (9.9)	18 (9.5)	57 (10.1)	9 (11.1)	2 (3.8)	14 (6.4)	14 (7.3)	39 (7.1)	3 (3.8)	6 (8.2)	9 (4.1)	9 (4.7)	27 (4.8)
4.	Bronchitis	22 (22.7)	22 (31.9)	40 (19.0)	29 (15.3)	113 (20.0)	13 (16.1)	6 (11.3)	21 (9.6)	17 (8.9)	57 (10.4)	11 (13.9)	7 (9.6)	11 (5.0)	9 (4.7)	38 (6.7)
5.	Asthma	0 (0.0)	0 (0.0)	7 (3.3)	5 (2.7)	12 (2.1)	0 (0.0)	0 (0.0)	2 (0.9)	5 (2.6)	7 (1.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Source : Computed
Note : Figures in parentheses denote percentage to number
N-Total number of persons in the sample households

Zone-wise Incidence of Airborne Diseases in SIPCOT Area

Table 4. Incidence of Airborne Diseases on Children

SL. NO.	Zones	Affected		Not Affected	Total
		Number	%		
1.	Zone-I	143	86.1	23	166
2.	Zone-II	96	71.6	38	134
3.	Zone-III	90	59.2	62	152
Total		**329**	**72.8**	**123**	**452**

Source: Computed

χ^2 **= 29.16**

Table 5. Incidence of Airborne Diseases on Adults

SL. NO.	Zones	Affected		Not Affected	Total
		Number	%		
1.	Zone-I	152	57.6	264	400
2.	Zone-II	133	32.3	279	412
3.	Zone-III	89	21.5	324	413
Total		**374**	**30.5**	**867**	**1225**

Source: Computed

χ^2 =

18.00

Table 6. Incidence of Airborne Diseases on Sample Households

SL. NO.	Zones	Affected		Not Affected	Total
		Number	%		
1.	Zone-I	295	52.1	287	566
2.	Zone-II	229	41.9	317	546

3.	Zone-III	179	31.7	386	565
Total		**703**	**41.9**	**990**	**1677**

Source: Computed

χ^2 = **36.59**

Age-wise Incidence of Airborne Diseases in SIPCOT Area

Table 7. Children and Adults Affected by Airborne Diseases

SL. NO.	Zones	Children Affected	P_1	Adults Affected	P_2	$\|P_1-P_2\|$	Z – Statistics
1.	Zone-I	143 (166)	0.86	152 (400)	0.58	0.28	11.30
2.	Zone-II	96 (134)	0.72	133 (412)	0.32	0.40	8.52
3.	Zone-III	90 (152)	0.59	89 (413)	0.22	0.37	8.60
Total		**329 (452)**	**0.73**	**374 (1225)**	**0.29**	**0.44**	**16.9**

Source: Computed
Note: Figures in parentheses indicate total

Table 8. Male Children and Male Adults Affected by Airborne Diseases

SL. NO.	Zones	Male Children Affected	P_1	Male Adults Affected	P_2	$\|P_1-P_2\|$	Z - Statistics
1.	Zone-I	78 (97)	0.80	83 (211)	0.39	0.41	6.8
2.	Zone-II	58 (81)	0.72	75 (220)	0.34	0.38	5.93
3.	Zone-III	48 (79)	0.61	43 (222)	0.19	0.42	7.12
Total		**184 (257)**	**0.71**	**202 (653)**	**0.31**	**0.40**	**11.4**

Source : Computed
Note : Figures in parentheses indicate total

Table 9. Female Children and Female Adults Affected by Airborne Diseases

SL. NO.	Zones	Female Children Affected	P_1	Female Adults Affected	P_2	$\|P_1-P_2\|$	Z - Statistics
1.	Zone-I	65 (69)	0.94	69 (189)	0.37	0.57	8.14

2.	Zone-II	38 (53)	0.72	58 (192)	0.30	0.42	6.0
3.	Zone-III	43 (73)	0.59	46 (191)	0.24	0.35	5.83
Total		**146 (195)**	**0.75**	**173 (572)**	**0.30**	**0.45**	**11.25**

Source: Computed

Note: Figures in parentheses indicate total

Table 10. Average Cost of Airborne Diseases of Sample Households Per Month (In Indian Rupees.)

Sl. No.	Airborne Diseases	Direct cost				Indirect Cost		
I.	**Zone – I**	Doctor Fees	Medical Expenses	Diagnostic Cost	Total	Travel Cost	Loss of Income	Total
1.	Cold	168(17.7) (34.5)	120 (11.2) (23.5)	0 (0.0)	144(13.7) (27.9)	113(13.6) (26.4)	102 (9.3) (19.5)	108(11.0) (22.6)
2.	Respiratory	124(13.2) (25.5)	97 (9.0) (19.0)	94 (13.2) (23.0)	105(10.0) (20.3)	110(13.3) (25.7)	224 (20.4) (42.8)	167(17.0) (35.0)
3.	Bronchitis	44 (4.6) (9.0)	51 (4.7) (10.0)	91 (12.8) (22.3)	62(5.9) (12.0)	87 10.5) (20.3)	92 (8.4) (17.6)	90(9.2) (18.9)
4.	Flu	73 (7.7) (15.0)	130 (12.2) (25.5)	138 (17.4) (33.7)	114(10.9) (22.0)	61(7.3) (14.3)	75 (6.8) (14.3)	68(6.9) (14.3)
5.	Asthma	78 (8.3) (16.0)	112(10.4) (22.0)	86 (5.1) (21.0)	92 (8.8) (17.8)	57 (6.9) (13.3)	30 (2.7) (5.8)	44 (4.5) (9.2)
Total		**487 (100)**	**510 (100)**	**409 (100)**	**517 (100)**	**428 (100)**	**523 (100)**	**477 (100)**
II	**Zone – II**							
1.	Cold	139(14.7) (41.6)	115 (10.7) (33.6)	0 (0.0)	127(12.1) (36.1)	76 (9.2) (31.0)	55 (5.1) (14.9)	66 (6.7) (20.2)
2.	Respiratory	68 (7.2) (20.4)	76 (7.2) (22.3)	88 (12.4) (34.4)	77 (7.3) (21.9)	50 (6.0) (20.4)	168 (15.3) (45.4)	109(11.1) (33.4)
3.	Bronchitis	35 (3.7) (10.5)	48 (3.7) (14.0)	39 (5.4) (15.2)	41 (3.9) (11.6)	38 (4.7) (15.5)	79 (7.2) (21.4)	59 (6.0) (18.0)
4.	Flu	36 (3.8) (10.8)	61 (5.7) (17.8)	75 (10.5) (29.3)	57 (5.4) (16.2)	45 (5.7) (18.4)	68 (6.2) (18.3)	57 (5.8) (17.4)
5.	Asthma	56 (5.9) (16.7)	42 (3.2) (12.3)	54 (3.4) (21.1)	50 (4.8) (14.2)	36 (5.5) (14.7)	0 (0.0)	36 (3.7) (11.0)
Total		**334 (100)**	**342 (100)**	**256 (100)**	**352 (100)**	**245 (100)**	**370 (100)**	**327 (100)**
III	**Zone – III**							
1.	Cold	39 (4.1) (30.7)	86 (8.0) (38.7)	0 (0.0)	52 (6.3) (31.0)	43 (3.9) (31.5)	63 (6.0) (30.0)	48 (4.9) (27.2)

2.	Respiratory	27 (2.8) (21.3)	52 (4.9) (23.5)	43 (6.0) (33.9)	40 (3.9) (23.8)	41 (4.9) (29.9)	70 (6.4) (30.1)	56 (5.7) (31.6)
3.	Bronchitis	29 (3.1) (22.8)	40 (5.0) (18.0)	36 (5.1) (28.3)	35 (3.4) (20.8)	25 (3.0) (18.2)	40 (3.6) (17.8)	33 (3.4) (18.6)
4.	Flu	32 (3.2) (25.2)	44 (4.1) (19.8)	48 (6.7) (37.8)	41 (3.9) (24.4)	28 (3.4) (20.4)	52 (4.7) (22.1)	40 (4.1) (22.6)
5.	Asthma	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Total		**127 (100)**	**222 (100)**	**127 (100)**	**168 (100)**	**137 (100)**	**225 (100)**	**177 (100)**
Overall		**948 (100)**	**1074(100)**	**792(100)**	**1048(100)**	**830 (100)**	**1098(100)**	**981 (100)**

Source: Computed

Note: Figures in right side parentheses denote percentage to overall total and below parentheses denote percentage to zone wise total

Table 11. Estimates of Cost of Airborne Diseases - MLRM

Sl. No.	Predictor Variables	Cost of Airborne Diseases (INR.)
1.	Zone (dummy)	0.090* (2.064)
2.	Income (*INR*)	0.089* (1.751)
3.	Number of disease affected persons	0.585** (3.401)
4.	Number of days of illness of the sample households	0.235** (5.252)
5.	Proportion of severely disease affected persons	0.450** (9.231)
R^2		0.679

Source: Computed

Note: Figures in parentheses are 't' values

** Significant at 1% level

* Significant at 5% level

Table 12. Willingness to Pay for Solving Air Pollution Problems

Sl. No.	Amount	Zone - I	Zone - II	Zone - III	Total
1.	Nil	70 (58.3)	85 (70.8)	91 (75.8)	246 (68.3)
2.	*INR* 25	38 (31.7)	35 (29.2)	29 (24.2)	102 (28.3)
3.	*INR* 50	12 (10.0)	0 (0.0)	0 (0.0)	12 (3.4)
4.	*INR* 75	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
5.	*INR* 100	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Total		**120 (100)**	**120 (100)**	**120 (100)**	**360 (100)**

Source: Computed

Note: Figures in parentheses denote percentage to number of sample

Table 13. Willingness to Accept for Air Quality

Sl. No.	Amount	Zone - I	Zone - II	Zone - III	Total
1.	Nil	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
2.	*INR* 25	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
3.	*INR* 50	2 (1.7)	0 (0.0)	0 (0.0)	2 (0.6)
4.	*INR* 75	12 (10.0)	19 (15.8)	35 (29.2)	66 (18.3)
5.	*INR* 100	106 (88.3)	101 (84.2)	85 (70.8)	292 (81.1)
Total		**120 (100)**	**120 (100)**	**120 (100)**	**360 (100)**

Source: Computed

Note: Figures in parentheses denote percentage to number of sample.

Table 14. Estimates of Willingness to Pay and Accept of the Sample Respondents : MLRM

Sl. No.	Explanatory Variable	WTP	WTA
1.	Constant	-25.92 (5.00)**	103.35 (23.25)**
2.	Age (in completed years)	-0.07 (0.98)	0.13 (1.94)*
3.	Education (years of schooling)	1.09 (5.38)**	0.34 (1.95)*
4.	Loss of Income (in *INR*.)	0.01 (1.05)	0.02 (1.03)
5.	Family Size (in *INR*.)	2.74 (4.39)**	1.00 (1.86)*
6.	Per capita income (in *INR*.)	0.02 (4.97)**	0.01 (1.76)*
7.	Household health cost (in *INR*.)	0.04 (2.54)**	0.01 (0.53)
8.	Zone – II (3 kms from SIPCOT)	7.65 (4.82)**	0.58 (0.42)
9.	Zone – III (6 kms from SIPCOT)	6.68 (3.82)**	3.71 (2.48)**
10.	Adjusted R Square	0.57	0.36

Source: Computed
Note : Figures in parentheses denote‘t’ value
** : Significant at 1% level
* : Significant at 5% level

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