ECONOMIC IMPACTS OF AIR POLLUTION ON HUMAN HEALTH AND PROPERTY VALUES: A STUDY OF COCHIN INDUSTRIAL AGGLOMERATION

Thesis submitted to the
Cochin University of Science and Technology
for the award of the degree of Doctor of Philosophy
Under the Faculty of Social Sciences

By

P.K.BABY
Reg No: 1901

Under the Supervision of

Dr. K.T. Thomson
Reader in Economics
***School of Industrial Fisheries*, CUSAT**

NOVEMBER, 2003

DEPARTMENT OF APPLIED ECONOMICS
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

School of Industrial Fisheries

Fine Arts Avenue, Foreshore Road, Cochin - 682 016, Kerala, India.

Dr. K.T. THOMSON M.A. Ph.D
Reader in Fisheries Economics
Ph: 91-484-354711

Residence
33/114 B, Kaleekal, Sowmya Nagar.
Alinchuvadu, Edappally, Cochin - 682 024,
Ph: 91-484-805142
E-mail : thomsonkt@rediffmail.com

Ref:

Date:..............................

Certificate

This is to certify that the thesis entitled '*Economic Impacts of Air Pollution on Human Health and Property Values: A Study of Cochin Industrial Agglomeration*' is an authentic record of the research work carried out by Shri. Baby P. K. under my supervision and guidance at the Department of Applied Economics, Cochin University of Science and Technology in partial fulfillment of the requirements for the Degree of Doctor of Philosophy and no part thereof has been submitted for any other Degree at any other Institution.

03-11-2003

Reader
(Supervising Teacher)

Contents

List of Tables

List of Maps

List of Figures

Chapter: 1

Introduction

Industrial revolution and subsequent growth of rapid industrialisation have caused serious threats to sustainable development of both developed and developing countries. While modern industries extracted various natural resources, other raw materials and energy from the environment to produce material goods and services, such uses and production processes have resulted in large scale emissions of wastes into the environment causing severe threats to traditional agrarian practices, suppressing the values of rural and urban property and reducing the quality of human life. Although most of the developed countries had responded to this social menace by developing a variety of technological, economic and legal regimes for regulating the polluting behaviour of firms, the developing countries have not attained sufficient progress in regulating industrial pollution and its influences on their economy and society due to lack of technological alternatives, failures of markets, institutions, government policies, mass poverty and illiteracy. The urge for attaining rapid industrialisation and the immediate transfer of benefits to local population subdued environmental concerns of sustainable development.

Environmental economists, who examined the impacts of industrialisation on the natural environment and human health in India have raised these contradictions of industrialisation [1]and argued for their immediate redressal through appropriate legal, fiscal and institutional regimes (Shaman, D., 1996; Kuik, O. J. et al., 1996; Sankar, U., 1998; Murty, 2000). Realizing the need for evolving a sustainable economy through appropriate environmental engineering, the Government has formulated a number of policies and enacted legislations[2]. Despite these initiatives, the process of industrialisation continues to inflict damages to human health and property values in many parts of the country[3] (Parikh, *et al.*, 1994; Abu backer, 1994; Cropper, 1997), including the State of Kerala which was believed to be least affected by industrial pollution[4].

---

[1] In India, the policy of rapid industrialization led to the growth of many big industrial cities. At the same time, however, out door air pollution has been constantly growing in these agglomerations due to concentration of industries and increased use of vehicles. Documents of Central Pollution Control Board disclose that the suspended particulate matter (SPM) in urban residential areas exceeded critical limits in many metros/cities.

[2] There were a number of legislations passed for protection of environment before and after independence. Some of these are the Indian Forest Act of 1865, Elephant Preservation Act of 1879, Bengal Smoke Nuisance Act of 1905, Bombay Smoke Nuisance Act of 1912, Motor Vehicles Acts of 1938 etc. Existing Legal institutions for environmental management in India are the result of a spate of environmental laws enacted by the Indian Parliament in the aftermath of the UN conference on the Human Environment in Stockholm, in 1972. The important air pollution prevention laws in India are: (1) Water (Prevention and Control of Pollution) Act, 1974; (2) Water (Prevention and Control of Pollution) Cess Act, 1977; (3) Air (Prevention and Control of Pollution) Act, 1981; (4) Environment (Protection) Act, 1986; (5) Ambient Air Quality Standards, 1986; (6) The motor vehicle act 1938, amended in 1938; (7)Public liability Insurance Act 1991; (8) Environmental Audit Notification, 1992; (9)Environmental Impact Assessment Notification 1994 etc.

[3] A recent study undertaken by the Indira Gandhi Institute of Development Research, Mumbai estimated that for every 10 microgram per cubic meter increase in atmospheric sulphur dioxide concentration, the annual social and health costs exceeds Rs.10 crores in Mumbai. The study also indicated that property values fell with an increase in suspended particulate matter in Chembur (Parikh et. al., 1994).

[4] The state of Kerala, the southern tip of India, is rich in natural resources and poor in industrial performance. It is generally accepted by the authorities that, Kerala is not highly polluted, compared with other states. Spenger, Thom, team leader of Indo Dutch project, Kerala State Pollution control Board, argued that based on the available data, the state's overall environmental status is acceptable. (Ernakulam Public hearing, 1999)

1.1 Statement of the Problem

A four decades long industrial development of the State of Kerala has brought in many changes on the use of natural resources and environment. The initial phase of industrialization in Kerala was based on natural resources like fisheries, cashew, coconut, coir, timber, and bamboo and other small forest produce, handlooms, minerals etc. Most of these industries were evolved as "clusters" where raw materials were abundant in supply. This scenario has changed since the second five-year plan with the active participation of the State towards industrialization. The industrial revolution led to the emergence of large factories with mass production capacities and majority of them located around river basins and in urban centres where population density is high. The number of working factories has increased to 18621 in 2001 compared to 9104 in 1980 (Government of Kerala, Economic Review 2000; 1980) Recent statistics of the Central Pollution Control Board reveals that Kerala ranks fourth in the case of industrial units closed down due to pollution (Govt. of India, Economic Survey, 2000-03). Another major causal factor of air pollution, the number of vehicles, has been growing at a rate of 10 percent per annum, leading to a concurrent increase in air pollution.

Moreover, traditional industries and new industries using modern technologies extract natural resources and environmental assets on large scales without paying the relevant price for such uses. It is unfortunate to note that most of the large-scale chemical and petrochemical industries, some in the public sector too, have started polluting the environment[5]. These in turn have led to the degradation of air, water and land, directly affecting livelihood and human health[6]. The 'Kerala Model of Development' has also been silent on these environmental and ecological issues due to its overemphasis on the role of the social sectors and quality of life[7].However, serious analytical studies on the impact of air pollution on Kerala economy, especially on the health of the people and on the changes in property values are not available[8]. This study attempts to overcome this limitation by

---

[5] It is reported that potential air pollutants like suspended solids, dissolved fluorides, and phosphates, free ammonia, ammoniac nitrogen, carbon powder, hexavalent chromium, acidic chemicals like SO_2, CO_2 Cl_2, HCl., etc., are emitted by these factories to the environment beyond the level of tolerance. It may be noted that some of these pollutants recorded by the experts of Pollution Control Board (PCB) and National Environmental Engineering and Research Institute (NEERI) are found to be harmful in many ways to the life and property of human population.

[6] Impacts are categorized in terms of human health, welfare (e.g., gains or losses apart from those associated with health, such as project related fishery yields), and environmental, including such ecological consequences as species preservation and diversity, and global impacts (i.e., large scale consequences, such as, climate change). [Asian Development Bank; 1996] see Freeman, M. III (1979) for some of these effects of air pollutants. pp: 18-23.

[7]Franke, R (1995) argued that environmental degradation is a major problem in Kerala. For instance, fishing resources seem to be declining in certain areas during the past decades. Similarly, salinisation, water logging, polluted rivers, and severe forest cover loss have lead to soil erosion, especially on the slopes of the Western Ghats Mountains. With its heavy population density and large number of micro environments packed together in a small, but varied landscape, Kerala is particularly vulnerable to ecological degeneration. Until fairly recently, it does not appear that the Kerala model focused attention on these issues.

[8] Antony, C.A (1998) has conducted a financial estimate of environmental pollution control and abatement schemes in Eloor-Edayar industrial belt of Cochin. He analysed the financial, economic, social and political implications of polluted environment in the study area in an Environmental Impact Assessment frame work. Some of the impacts of pollution and its abatement measures were also examined. The study concluded that the environment in the study area is heavily polluted and spread over 1,10,000 people and 65,000 domestic animals and birds. Agriculture and human health were seriously affected by pollution in the industrial belt. However, the study hasn't used any proper valuation methods (observed behaviour or hypothetical methods), which are used to capture use, non-use and option values of an environmental good, especially when markets fail. The stressor-impact information provided in the study was useful, but the benefits or losses (in health or property values) to households or society at large, due to a change in environmental quality were not estimated and evaluated in the study.

undertaking a detailed analysis of the economic impacts of air pollution on human health and property values around the Cochin industrial agglomeration in Kerala.

1.2 Research Questions

This study aims to answer the following questions:

1. What is the relationship between air pollution, human health and property values and
2. How has it affected the prices of property and the health of human population in and around the industrial agglomeration

1.3 Objectives

More specifically, the study proposes the following objectives

1. To provide a systematic descriptive documentation of the nature of air pollution of the Cochin industrial agglomeration.
2. To estimate willingness to pay for morbidity reduction due to air pollution in observed and hypothetical markets.
3. To estimate the value of welfare loss in the purchase of property due to reduced air quality.

1.4 Economic Impacts of Air Pollution: Framework of Analysis

Industrial sector in Kerala is one of the major productive and wealth creating sectors. However, it remains as a major polluter, resulting in the degradation of the health of local population and reduction in property values. Pollution is defined as 'an *undesirable state of the natural environment being contaminated with harmful substances as a consequence of human activities'* (Cognitive Science Laboratory: Princeton University[9]). Air pollution is the '*contamination of the atmosphere by substances that, directly or indirectly, adversely affect human health or welfare. It results from human activities, both deliberate releases (as from smokestacks) and fugitive emissions (as dust blown from streets or fields), and from natural sources, including sea spray, volcanic emissions, pollen, etc*'. (National Institute for the Environment[10], Washington D.C) The problem of pollution and its management is found in history and is well debated in various disciplines[11]. Economic definition of pollution is dependent up both physical effect of waste on the environment and the human reaction to that physical effect. In economic parlance, there has been an

---

[9] www.cogsci.princeton.edu/cgi-bin/webwn

[10] www.cnie.org/nle/AgGlossary/letter-a.html

[11] There are records of Romans complaining about the 'stink of money chimneys' (Schoenbaum and Rosenberg 1991). Spanish explorers landing in the sixteenth century noted that smoke from the Indian campfires hung in the air of the Los Angeles basin (Ruff .E. Larry 1972). Pollution control laws in other parts of Europe dates from the Middle Ages. These issues and many more contemporary issues like biodiversity degradation, global warming, climate change etc. have been analysed both by natural scientists, engineers and social scientists. Dorfman (1972) argued that pollution must be understood in economic terms. Approaches to pollution based on technology, politics, law and ethics are bound to have disappointing results, because they ignore the fact that pollution is an economic problem. pp: 3

uncompensated loss of human welfare due to the imposition of an external cost[12] related to emissions into the air (Turner, Kerry; 1994). Environmental economists argue that the damages due to air pollution depend on the assimilative ability of the environment. If the emission loads exceed absorptive capacity, pollutants accumulate in the environment (Hanley, *et al.,* 1997), causing damages to the material well- being of the society.

It was Pigou (1920) who first analysed the impact of pollution by distinguishing between the private costs and social costs. The polluting firm, most often, externalises its costs of abatement causing divergence between the private and social costs. When these costs diverge, markets fail to perform efficiently. The divergence between costs and benefits is the fundamental cause of pollution of all types (Dorfman and Dorfman; 1972). Market failure occurs when prices understate the full range of services provided by an asset or simply do not send signals to the market about the value of an asset. One of the most important sources of market failure is the presence of externalities or spillovers[13]. There are many other cases of market failure for environmental assets, such as, incomplete markets, non-

---

[12] i.e., health damage, increase in mortality or morbidity etc.

[13] Externalities refer to the costs or benefits imposed by the consumption or production activities of individuals on the rest of the society for which no payment is made. Such costs are outside the market system and are not reflected in relative market prices. (Hanley *et al.,* 1997). Through industrial pollution, society incurs significant costs by reducing the assimilative capacity of the environment. These costs are external costs and thus pollution becomes an externality. (Tietenberg, 1988)

exclusion, non-rival consumption, non-convexities and asymmetric information (Hanley, *et. al.*, 1997)

Pollution externalities alter natural ecosystems and human life in many ways. For instance, air pollution influences natural vegetation, productivity of land, other economic activities, human health, property prices and very many varieties of ecosystem services. Although all these issues demand detailed critical examination, the major focus of our thesis, however, is on how air pollution influences human health and property values.

The incidence of air pollution on human health ranges from morbidity[14] to mortality. (Murty and Kumar, 2002). Morbidity can be classified in a variety of ways based on the duration or intensity of illness as chronic or acute, on the degree of impairment of activity which decides the inability of the affected person to undertake normal work or on the type of symptoms that varies from person to person. The degree of impairment of activity is an important way of measuring morbidity. There are several categories of degrees of activity impairment, namely, Restricted Activity Days[15] (RAD), Bed Disability Days[16] (BDD) and Work days

---

[14] Morbidity is defined by the U. S. Public Health Service as, 'a departure from a state of physical or mental well being, resulting from disease or injury, of which affected individual is aware (Peterson, 1975).

[15] Restricted Activity Days are those on which a person is able to undertake some, but not all, activities (Freeman, 1993)

Lost[17] (WDL). Following the guidelines suggested by the United States Department of Health, the present study clubs these three categories under one head, RAD (U S Department of Health, 1964).

Mortality, on the other hand, refers '*to a well defined event – death – which for ceremonial and legal reasons almost always is noted and made part of an official record*' (Freeman, 1993). Both morbidity and mortality have attained considerable importance for estimating willingness to pay for improved health. However, this work is concentrated on morbidity alone because it has varying degrees of illness or injury, with multi dimensional impacts.

The second issue examined in this inquiry is on the relationship between air pollution and the value of residential property. This relationship depends mainly on various environmental, structural and neighbourhood characteristics they possess. Environmental characteristics include the factors which determine environmental quality, such as, SO_2, NOX, and SPM, distance to lake or river etc. Structural characteristics include plot size, number of rooms, garage space, type of flooring, type of roofing, age of house etc. and neighbourhood characteristics include level

---

[16] Bed Disability Days are those in which a person is confined to bed, either at home or institution (Freeman, 1993).

[17] Work days Lost are those on which a person is unable to engage in ordinary gainful employment(Freeman, 1993).

of traffic, distance to central business district, distance to nearest industrial zone, slope of property etc.

In absence of ownership and efficient pricing, special techniques are needed to analyse economic impacts of environmental changes. One of the popular approaches[18] to analyse the economic impacts of air pollution on the health of human population and residential property values is centred on identifying and monetising the relevant costs and benefits of an environmental change. Monetary values of changes in human health that are associated with environmental changes are estimated either using 'indirect observed' approach [household production function] or the 'hypothetical market approach' [Contingent Valuation Method (CVM)] (Murty, 2000). While a standard production function approach is adopted in the former method to estimate the willingness to pay (WTP) for restricted activity days affected by air pollution, the latter method resorts to hypothetical markets for the elicitation of values[19].

---

[18]The methods of estimating values for environmental goods are mainly classified into two: 'Physical linkage methods' and 'Behaviour linkage methods'. Physical linkage method assumes that there is some sort of technological relationship between environmental good and the user. This relation ship may be either technological of biological. The behaviour linkage methods are mainly classified into two: 'observed behaviour' and 'hypothetical'. The important observed behaviour methods are Simulated markets, Travel Cost, Hedonic Property Value, Avoidance Expenditures, and Referendum Voting etc. Major hypothetical methods are Bidding game (willingness to pay questions), Contingent Ranking, Contingent Referendum etc. (Mitchell and Carson, 1989). Some other methods are also applied in valuation of health damage, such as, Cost of Illness, Human Capital Approach, Value of Statistical Life (United Nations; 1997)

[19] A detailed review of such studies is given in chapter 2.

1.4.1 Air Pollution and Health: The Production Function Model

Environmental pollution reduces people's well being through the following ways. (1) Medical expenses associated with treating pollution-induced diseases including the opportunity cost of time spent for obtaining the treatment, (2) Lost wages (3) Defensive or averting expenditures associated with attempts to prevent pollution-induced disease, (4) Changes in consumption pattern, (5) Disutility associated with the symptoms and lost opportunities due to diseases and (6) Changes in life expectancy or risk of pre-mature death. (Freeman, M, 1993). Therefore, the welfare loss due to air pollution could be estimated in terms of increased morbidity.

Economists have used a number of approaches to determine the monetary value of reduced morbidity. A formal model used for deriving values of reduced morbidity, based on health production function, was first developed by Grossman (1972). Cropper (1981) introduced a pollution variable into the function and later Harrington and Portney (1987) extended the model to examine explicitly the relation between willingness to pay (WTP) and a reduction in pollution. Alberini and Krupnik (2000) have applied this model to estimate willingness to pay to avoid health damages. The model used here is a variant of Harrington and Portney (1987).

More specifically, the health production function is expressed as

$$S = s(C, M, H, K)$$

Where, S= Number of Sick Days

C = Environmental Quality

M = Mitigating Activities

K = Stock of Social Capital (such as education, sex....)

H = Stock of Health Capital

The Utility function of the individual can be defined as

$$U = u\ (Y, S, C, L, I)$$

Where,

Y = any private good, taken as numeraire

L = leisure

I = Income

Individual's budget constraint is written as,

$$I = I^* + Pw\ (T - L - S) = Y + Pm.M$$

Where,

Pw = wage rate

I^* = non labour income

T = total time available

Pm = price of mitigating activities

Individual maximizes Utility (2) subject to the budget constraint,

$$Max\ Z = u\ (Y, S, C, L, I) + \lambda \left(I^* + Pw\ (T - L - S) - Y - Pm.M\right)$$

Estimating the demand function for mitigating activities, one obtains the marginal willingness to pay as:

$$MWTP,\quad \frac{\partial I}{\partial C} = P_W \frac{\partial S}{\partial C} + P_M \frac{\partial M}{\partial C} - \frac{\partial U/\partial S}{\lambda} \cdot \frac{\partial S}{\partial C}$$

1.4.2 Air Pollution and Property: The Hedonic Model

The welfare benefit in property values due to reduced air pollution is estimated using the hedonic property value model. The model used here for observing the relationship between air pollution and property value is based on Freeman (1979). Following Freeman, Pearce and Turner (1990) and Bateman (1993) Parikh *et al.* (1994) have applied the model to estimate property values. Based on this basic model, the study also estimates Marshallian consumer surplus, as a measure of welfare benefits from reduced levels of air pollution. The model is specified below.

Consider the price of a residential location (*Phi*) as a function of structural (*Si*), neighbourhood (*Ni*) and environmental characteristics (*Qi*).

$$Phi = Ph(Si, Ni, Qi)$$

The utility function of the individual who occupies the house is,

$$u(X, Si, Ni, Qi)$$

If there is an improvement in environmental characteristics from qj^0 to qj^1, the value the individual places on such improvements (*Bij*) could be estimated by integrating the implicit price function with respect to *qj*.

$$Bij = \int_{qjo}^{qj1} bij(qj, Qi^*, Si, Ni, Gi)\partial qj$$

Where, *Gi* is the socio-economic characteristics.

The value obtained by integrating the inverse demand function with respect to the implicit price is interpreted as the consumer surplus.

The inverse demand function assumes the form,

$$imprice = e^{a0}.Gi^{a1}.Si^{a2}Ni^{a3}.Qi^{a6}$$

Consumer surplus is calculated by integrating the inverse demand curve with respect to the implicit price and calculating the definite (Reimann) integral by observing the old and new level of *Qi*, planned by the policy maker.

1.5 Methodology

This study begins with a detailed description of the basic characteristics of the selected industrial agglomeration including the nature and incidence of air pollution caused by industrialisation of Kerala economy in the recent past. It then concentrates on the identification, quantification and analysis of the major economic impacts of air pollution in the study area.

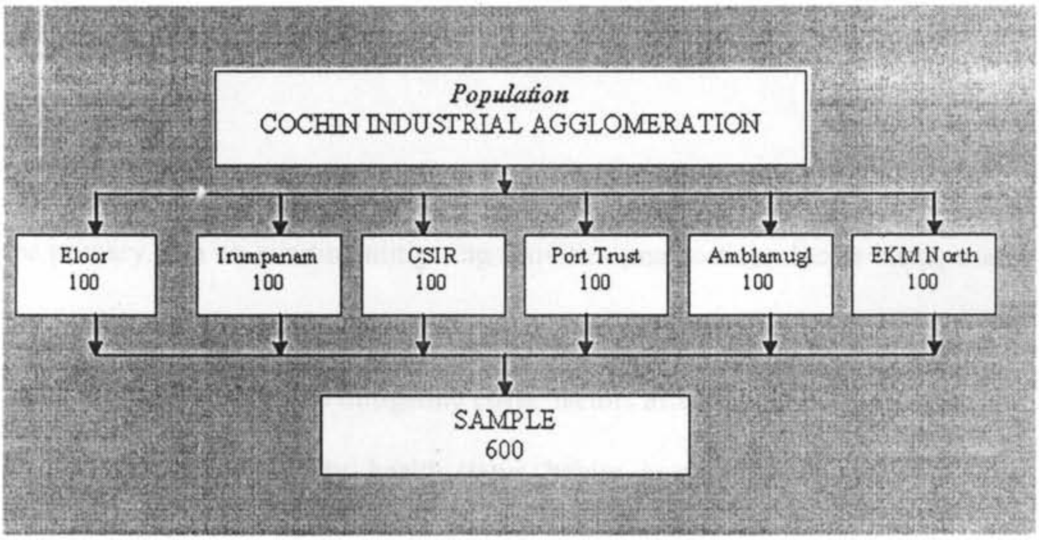
1.5.1 The Study Area

The study is conducted in the Cochin industrial belt in the state of Kerala *(see map 3.5 in chapter 3)*. Cochin Industrial agglomeration is a geographical space, consisting of the Cochin Corporation, the Kalamassery Municipality and three panchayaths, viz, Vadavucode- Puthercruz, Thiruvankulam and Ellor. This area has been identified as the industrial capital of Kerala and hence inhabits a large number of factories both in the private and public domain. The Central Pollution Control Board in collaboration with the State Pollution Control Board identified Cochin as one of the problem areas in the country. It ranks first in both number of vehicles and number of registered factories (see chapter 3 for details). It is also reported that potential air pollutants like suspended solids, dissolved fluorides and phosphates, free ammonia, ammoniac nitrogen, carbon powder, hexavalent chromium, acidic chemicals like SO_2, CO_2 C_{12}, HCL, etc. emitted by these factories in to the environment are one of the highest compared to other districts of the State and are even beyond the level of tolerance. It is further noted that most of these pollutants recorded in this area are found to be harmful in many ways to the life and property of human population (Pollution Control Board (PCB): 2000; National Environmental Engineering and Research Institute (NEERI), 2000).

1.5.2 Population and Sample

The universe of the study Cochin industrial agglomeration, constitute, 130780 households including 695357 number of population. The households chosen to participate in the survey was selected using a two stage stratified sampling procedure. In the first stage, the agglomeration is divided into six strata according to the distribution of air quality monitoring stations of the State Pollution Control Board. These stations are Ambalamugal, Eloor, Port Trust, CSIR Complex, Ernakulam North and Irumpanam. From these regions 100 households with in a radius of 1000 meters from the respective monitoring stations have been selected for intensive examination in the second stage. The figure 1.1 explains the sampling procedure adopted.

Figure: 1.1
Sampling procedure



1.5.3 Variables and Collection of Data

The study is based on both secondary and primary data. The National Ambient Air Quality Monitoring data has been collected from the publications of Central Pollution Control Board. These data were used as the measure of air pollution. Details regarding study area are collected from the records of respective local panchayath/ municipality/ corporation and zonal office of Pollution Control Board at Cochin. Other relevant secondary data, regarding pollution health impacts, epidemiological data etc. are collected from various published and unpublished sources, institutions such as State Pollution Control Board (PCB), National Environmental Engineering Institute (NEERI), NGOs such as, Kerala Sashtra Sahitya Parishat, Green Peace, Periyar Malineekarana Virudha Samithy and Industrial units.

The primary data on averting/mitigating activities (medication, doctor visits, use of folk medicines, installing air purifier etc.), workdays lost, number of sick days, family details, averting and mitigating costs, factors affecting property values, sales price of residential property, health status, habits, hospital admissions, and other socio economic variables, such as, education, household income etc. are collected using a structured schedule (*see Appendix* I *for schedule*).

1.5.4 Primary Survey

A primary survey covering family details, environmental quality, factors influencing human health, other socio economic variables, willingness to pay for avoided heath risks and factors affecting property values was conducted among 600 households at six centres in the Cochin industrial agglomeration during the period of June 2001 – January 2002 in a face to face interviewing method. To estimate their WTP to avoid symptom days, five symptoms (coughing, itching and smarting eyes, breathing trouble, acute bronchitis and asthma attack) were given. The descriptions of these symptoms were given in five separate cards and were distributed. After giving a detailed picture of the exposure-response functions in the area, people were asked to choose one of the symptom slip, which ranked as the worst one in the light of previous disease experience. The first part of the question explicitly reminds people about their costs on mitigating and averting activities and how it affects their family budget constraint. Then they were asked, their *willing to pay Rs. 200 to eliminate these symptom days.* Rs. 200 was obtained as an average minimum cost of Illness from the preliminary survey. In the next iteration, to obtain their maximum WTP, people were asked to bid an amount to avoid the symptoms for 1-7 days for the next 12 months. If the answer was in the affirmative, people were asked to increase amounts from Rs. 200 to a maximum, using the bids and if the answer was in the negative, the amount was reduced by a certain rate down to what the respondent was actually willing to pay.

The survey was conducted among 100 respondents each from six strata of the sample.

1.5.5 Estimation

SPSS and E-views were used for statistical calculations.

1.6 Scope of the study

Industries pollute environment and the society incurs significant loss of welfare from this, due to reduced assimilative capacity of the environment. This study highlights that air pollution generates costs which are external to the industry (Tietenberg: 1988). As emphasised in the beginning of this chapter, pollution being an externality creates serious damages to human health, agriculture, livestock, fisheries and property values. It is unfortunate, however, that such issues are often marginalised in academic discourses on development, even while environment-friendly industrialisation policies are formulated.

Our study has some definite advantages in understanding the manner in which air pollution affects the economic activities of one of the most important industrial agglomerations of the state of Kerala. For instance, the welfare losses due to the incidence of air pollution have been estimated using established environmental economic methodologies. These results can be used for evolving environment-friendly industrialisation strategies for Kerala economy. In fact, a number of people's science movements and the civil society have been demanding such redressal packages for the sustainable development of Kerala[20].

At the same time, this study is probably the first attempt to conceptualise and quantify the environment-economy interaction of air pollution in Kerala. It may however, be mentioned that our study concentrates only on the economic impacts of air pollution on human health and property values while many other parameters remain outside the domain of our limited scientific inquiry. More detailed formulations and studies are therefore required to understand these processes in order to formulate policies for a sustainable Kerala model of development.

1.7 Plan of the Thesis

The thesis is divided into six chapters. The first chapter introduces the study, a framework for analysis and the underlying methodology adopted in the study. The second chapter reviews the relevant literature. It aims to establish the complex interaction among air pollution, human health and property values. In the third

[20] A number of local people's movement, such as, Periyar Malineekarana Virudha Samithy, Karimugal Carbon Malineekarana Virudha Samithy etc., leading NGOs such as, Kerala Peoples Science Movement (KSSP), Green Peace etc. and many other grass root agencies have raised issues and concerns regarding various environmental problems faced by the state. They are often organizing demonstrations and agitations against the government and polluting industries. They are demanding immediate reallocation of institutional and policy options towards sustainable development. Pollution-health issues, along with deforestation, paddy conservation, disruption of backwater ecosystem, sand mining, depletion of resources, such as, fisheries, water resources, and allocation of private property rights to public goods and services such as bridges, health have raised serious discussions regarding sustainability of Kerala pattern of development. They are demanding immediate reallocation of institutional and policy options towards sustainable development.

chapter we outline the status of air pollution in the Cochin industrial agglomeration. The fourth chapter presents an analysis on the influence of air pollution on human health in the study area. An attempt is also made in this chapter to quantify these relations using production function and contingent valuation methods. This is followed by a detailed analysis of the impact of air pollution on property values in chapter five. Chapter six provides the summary and conclusions of our study.

Chapter 2

Economic Impacts of Air pollution on Human Health and Property Values: A Brief Review of Literature

Social scientists argue that modern industries, while emitting pollutants into the earth's surface, economise on their transformation costs. Since such emissions ruin the overall health of the human population, the general public attempt is to mitigate the negative externalities of air pollution both collectively and individually. While their collective action, organised through various social resistances and pressure tactics, influences the crafting of appropriate legal and institutional arrangements for pollution abatement, a large number of individual households still have to incur a variety of private costs to mitigate the impacts of air pollution. Therefore, the monetary benefits accruing to the industry and the costs borne by individual households and society have to be properly estimated. A number of environmental economists were involved in the estimation of such costs and benefits through various measurement techniques. This chapter attempts to make a detailed critical evaluation of the major studies undertaken by economists on the impacts of industrial air pollution. However, the survey reviews only those studies dealing with the impact of air pollution on human health and urban property values. This chapter is divided into two sections. The first section reviews studies on valuation of health damage and the second section reviews studies on the valuation of residential property. Theoretical and empirical studies are separated in subsections. The third section summarises the major conclusions of this chapter.

2.1 Air Pollution and Its Influences on Human Health: A Review of Studies

Air quality is an important environmental resource and its deterioration has many serious impacts on human well being. A number of scientific studies that emerged over the past several years have proved the relationship between air pollution and its impact on vegetation, human health, property prices, aesthetic effects, fisheries, physical materials etc. (Central Pollution Control Board, 2000). Air pollution threatens human health and its effects are very complex.[21] Health effects from SPM depend on particle size and concentration and vary with daily fluctuations in PM_{10} and $PM_{2.5}$ levels. They include acute effects such as increased daily mortality, increased hospital admission rates for exacerbation of respiratory disease, fluctuations in the prevalence of bronchodilator use and cough, and reduction in lung function (e.g. peak flow reductions).The particles may influence on settling and cause external effects[22].

---

[21] Poor air quality has impact on both morbidity and mortality. For example, the magnitude of the London fog of 1952, which affected such a large number of people, was the first incident that made people aware of the damage done to the atmosphere due to industrialization. The SPM levels increased manifold and resulted in over 4000 deaths. Depending on their source and interactions with other components of the air, they have different health impacts. Since these pollutants are generally concentrated in and around urban areas, the outdoor pollution levels are far higher in urban areas. The major air pollutants and its health effects are given in annexure 2.1.

[22] For example, effects on skin. However there are certain group of particles which do not cause direct effects at their site of deposition but can pass into the blood stream and act as systemic poison. For example, trace metals. The fine particles may cause irritation of bronco spasm, pulmonary oedema and allergic alveolitis, while certain moulds of certain larger particle size cause

Nitrogen dioxide and its reaction with hydro carbon results in airway reactivity and pulmonary effects, respiratory morbidity in children, effects on immune system and host defences and chronic lung diseases. Sulphur dioxide is highly water soluble and most of the gas inhale via the nose is absorbed by nasal mucosa, with little reaching to lower portions of respiratory track. As activity level increase and breathing mode shift from predominantly nasal to more oro-nasal inhalation the penetration of sulphur dioxide may increase. The acidic aerosol formed due to presence of sulphur dioxide can cause acute effects on pulmonary function and respiratory symptoms occur but alteration in clearance mechanism and possible long term exposure effects are also of much concern.

As described above air pollutants creates wide spread impacts on health of human beings in a variety of ways[23]. Two links must be established in estimating the

---

obstructive lung disease. Particles penetrated into the human body during breathing process are deposited into the respiratory system causing local effect in respiratory tract. The acute effects of particulate air pollution results in changes in respiratory health status and depict several respiratory health symptoms. The symptoms are often recorded into upper respiratory symptoms such as stuffy and running nose, sinusitis, sore throat, wet cough, head cold, hay fever and red eyes. The lower respiratory symptoms include wheezing, dry cough, phlegm, shortness of breath, chest discomfort and pain. The cough is most frequently reported symptoms dues to continuous exposure in high particulate matter laden ambient air. Other important effects of particulates are bronchitis, pneumoconiosis, cancer, systemic poisoning etc. Similarly, uptake of oxides of nitrogen during breathing is also dangerous to health.

[23] As stated in the previous chapter, health effects or air pollution ranges from morbidity to mortality and this study focuses on morbidity effects. In addition to these two, chemical contaminants can produce subtle physical and mental changes in the people. For example, relatively lower levels of lead in blood have been implicated in decrements to IQ in children (U.S Environmental protection Agency, 1986)

values of these changes. The first is the link between air pollution and health status and the second is that between change in health status and its monetary equivalent, willingness to pay or willingness to accept compensation[24] (Freeman, 1993). The following two sections discuss the measurement techniques for valuing changes in morbidity and its empirical applications.

2.1.1 Theoretical Models and Conceptual Issues

Economic methods for valuing health impacts are broadly classified into two broad categories, namely, Physical Linkage Methods and Observed Behaviour Methods.

(i) Physical Linkage Methods

Physical linkage methods are valuation methods that first establish cause-effect or dose-response relationship and then value the impacts of environmental change (United Nations 1997). This method assumes that there exists some sort of technological relationship between the environmental good and the user. The procedure for estimating heath effects under this method involves three steps. The first step is to determine the relationship between changes in exposure to environmental pollution[25]. The second step is to use this relationship to predict

---

[24] There are two alternative strategies for environmental change that affect human health. The first strategy is to develop a comprehensive model of individual behaviour and choice in which environmental quality is one of the determining variables. The second strategy is to deal with two links separately. Economic values of changes in health status are derived first and they would then be combined with independently derived predictions of heath change (Freeman 1993)

changes in mortality and morbidity associated with specific changes in air pollution and third step is to derive monetary measures of changes in health status. The important physical linkage methods are cost of illness, human capital approach and statistical value of life (United Nations 1997) .

Cost of Illness approach (COI)

Cost of Illness approach (COI) measures the cost of Environmental damage in terms of direct outlays for the treatment of illness (hospital care, cost of medicines, costs of services of physicians and other medical personnel) plus indirect losses in output due to illness measured by the social cost of lost earnings (Rezeler, 1993). This approach, however, does not account for averting expenditure and the value of personal pain, suffering and inconvenience associate with illness. Cropper and Freeman (1990) suggested that society's willingness to pay to reduce the health risk should also be added to get full social costs of illness.

Human capital (HK) Approach

Human capital (HK) approach for valuing lives assumes that the value of an individual alive is what he or she produces and that productivity is accurately measured by earnings from labour (Freeman 1993). A sum of the numerical values

[25]For human health, this is derived through a combination of biomedical studies and statistical analy sis.

of either morbidity or mortality and the unit cost of treatment or death will provide the monetary value of health damage according to this method.

Statistical Value of Life

Under this method the value of human life is analysed by the behaviour of people in paying for reduction in risk to their life or accepting compensation for undertaking risky jobs (United Nations, 1997).

For social scientists and economists, the application of Physical Linkage methods involves severe difficulties in proving the cause-effect relationship. Murty (2002) argued it is the job of the environmental scientists, engineers and ecologists to identify and estimate the relationship between policy changes and environmental quality as well as the relationship between the environmental quality changes and environmental services. Monetary valuation as the next stage has to be done by economists. Hence social scientists relay more on behavioural approaches.

(ii) Observed Behaviour Methods

Economists have used different techniques for valuing reduced morbidity due to pollution. They are Avoidance Expenditure Method and Contingent Valuation Method.

Avoidance Behaviour Approach.

This approach infers people's willingness to pay to reduce ambient pollution levels from the amount of money they spend to avoid exposure to air pollution (for example, by installing air filters) or to mitigate its effects (Cropper and Freeman 1997). According to this approach, people use life saving consumer goods such as seat belts or smoke detectors until the marginal cost is equal to the benefit of reducing the probability of death. According to Blomquist (1979) the value of life or loss of time can be estimated by dividing the annual cost of averting behaviour by the reduced risk of death or illness.

Households avoid health damages either by avoiding exposure to pollution in the first place, or by mitigating the effects of exposure once they occur (Cropper and Oates 1992). Grossman (1972) first used the household production model to examine health decisions. Cropper (1981) introduced a pollution variable in to the health production function. Gerking and Stanley (1986) used a household production function model for health stock in a single equation framework recognizing the role of medical care. The Gerking and Stanley analysis uses two measures of health capital. The first determinant is self reported existence of chronic illness; the second is the number of years illness has been present. Harrington and Portney (1987) extended the household production function model introduced by Grossman to examine explicitly the relationships among willingness to pay for a reduction in pollution, reductions in cost of illness, and changes in defensive expenditures. Bartic (1998) argues that it is theoretically possible to derive WTP measures based on averting expenditures alone, but in order to do so one needs to rely on extensive information about the households production technology, especially in the presence of joint averting behaviour[26]. Dickie and Gerking (1991a) use various aspects of a person's health status to measure health stock directly. They used a set of health symptoms in estimation of functions hypothesised to be associated with air pollution. Dickie and Gerking (1991b) estimate random effects probit models for doctor visits as a function of pollution, proxies for individual stock of health, price of medical attention and use demand for doctor visits to compare WTP with the cost of doctor visits. Depending on the specification of the probit models upon which the demand curve is based, they find that WTP can be two or four times as large as expenditure on doctor visits.

Alberini and Krupnick (1997) explore the appropriateness of concentration response function transfers by comparing the two health studies in Los Angeles and Taiwan. It used daily records from a dairy-type epidemiologic study in Taiwan to fit logit equations predicting the probability of experiencing minor acute respiratory symptoms as a function of pollution and weather variables, individual characteristics, health backgrounds and proxies for reporting effects. Cropper and

[26] For example, running air conditioner acts as a filter to pollution during high pollution days, but also makes the home more comfortable.

others (1997) has used a similar format to estimate the health damages associated with air pollution in Delhi.

Contingent Valuation Approach

There are many problems associated with using indirect market approaches to estimate value reduction due to air pollution. When no appropriate averting or mitigating behaviour exists, indirect methods can not be used to estimate the morbidity benefits of reducing air pollution. In addition 'non-use values' are not measured by indirect market methods. Non-use values refer to the benefits received from knowing that a good exists even though the individual may never experience the good directly (Cropper and Oates, 2000).

This suggests that the 'direct questioning' (Contingent Valuation) can play a role in valuing the benefits of pollution control. Contingent Valuation, first proposed by Ciriacy-Wantrup (1947) and first applied by Davis (1963) brings out individual valuations of a hypothetical commodity, such as a possible improvement in health, using survey research methods. This method was used for valuing recreation benefits, air quality, visibility and aesthetic environmental preferences in the past. A Contingent Valuation study must incorporate (a) a description of the commodity to be valued (b) a method by which payments are to be made and (c) method of eliciting values. The method has been used extensively to obtain WTP values for avoided morbidity, such as, avoidance of asthma-related illness (Rowe and

Chestnut, 1985, Dickie and Ulery, 2001). Despite the advances made in Contingent Valuation Methodology[27], many remain doubtful. The most serious criticisms are that responses to Contingent Valuation questions are hypothetical rather than actual willingness to pay (WTP). Other criticisms are, (a) the possibility that individuals may behave strategically in answering questions either overstating or understating willingness to pay (WTP), (b) the fact that individual may not be sufficiently familiar with the commodity and (3) the difference between willingness to pay (WTP) and willingness to accept (WTA)[28]. The accuracy of Contingent Valuation studies has been debated by many scholars[29]. Mitchell and Carson (1989) provide a standard reference on Contingent Valuation.

---

[27] The CVM has two advantages over indirect methods. First, it can deal with both use value and non-use values, where as indirect methods cover only the former and involve weak-complementarity assumptions. Secondly, CVM answers to WTP questions go directly to the theoretically correct monetary measures of utility changes.

[28] Values can also be measured as an individual's 'willingness to accept' (WTA) compensation for accepting a specific degradation of environmental quality. There has been a significant debate over the past two decades about the disparity between willingness to pay (WTP) and willingness to accept (WTA). [See Brown, Thomas, C and Robin Gregory, 1999; Kolstad, Charles and Ronaldo M. Guzman; 1999]. An important difference between these two measures is that WTP is limited by an individual's income, while WTA is not. Empirically WTA is more difficult to estimate. It is often impossible to identify the upper bound on values. Due to these reasons, the WTP of affected individuals is most often used to asses benefits or damages (Asian Development Bank,1996).

[29] In Contingent Valuation Studies preferences revealed through actual behaviour have great credibility in economics. However, statements by economic actors about how they would act under hypothetical situations are to be viewed with great suspicion (Bishop, Richard *et. al, op. cit* 1995). There are several issues that arise in examining CVM studies. Many early studies using CVM were concerned with the large number of bias that could result from using this method. Mitchell and Carson (1989) give a comprehensive account of biases in CVM. 'Bias' means a systematic over or under statement of true WTP. The possible sources of such bias include the starting point in bidding games (Boyle et al., 1986), the choice of bid vehicle (Rowe et al., 1980), and hypothetical market bias (Bishop and Heberleine, 1979). Another area of concern is strategic bias. If respondents believe that bids will be actually collected, they may understate their WTP for a welfare improving change because environmental goods are typically non excludable in consumption (Hanley, Shogren and White, 1997). Another issue related to the examination of CV studies is how to value the commodity, such as the reduction of symptom days. A second issue common to all CVM studies is

Alberini (1995) fitted an interval-data model to discrete choice Contingent Valuation (CV) data with a follow-up when the willingness to pay (WTP) responses were generated by a bivariate process. He fitted a bivariate model when the most parsimonious statistical framework was an interval data model. The results suggest that the model selection strategy might favour the interval data model, even though the correlation between willingness to pay (WTP) values is less than perfect. Based on the same theoretical frame work, Lauraine, Ostro and Vadakan (1997) designed a willingness to pay (WTP) survey in Bangkok by obtaining information about how people would value a reduction in frequency of days with respiratory symptoms.

Alberini and Krupnick (2000) compare the Cost of Illness and Willingness to Pay estimates of damages from minor respiratory symptoms associated with air pollution, using the data from a study in Taiwan. A Contingent Valuation Survey was conducted to estimate willingness to pay to avoid minor respiratory illness. Health diaries were analysed to predict the likelihood and cost of seeking relief from symptoms and of missing work. As predicted by economic theory, willingness to pay was greater than the COI.

---

whether the respondents carefully consider the budgetary implications of their responses. Mitchell and Carson (1989) explain validity and apply it to CVM in this way: '*the validity of a measure is the degree to which it measures the theoretical construct under investigation. This construct is in nature of things, unobservable; all we can do is to obtain imperfect measures of that entity. In the Contingent Valuation context the theoretical construct is the maximum amount of money the respondents would actually pay for the public good if the appropriate market for the market good existed.*'

Alberini *et al.* (1997) and Alberini and Krupnick (1998) formulated a closely related version of the household production model in which willingness to pay is written as the effect of pollution on illness times the marginal value of illness. As Cropper and Freeman (1991) argue, this approach allows them to combine an epidemiological study with a Contingent Valuation survey in order to estimate willingness to pay to avoid air pollution-related illness episodes in Taiwan. The epidemiological portion of the study used air pollution data that were matched to health diary data collected from study participants. The Contingent Valuation portion was administered to participants at the end of the study and it focused on describing and then valuing the most recent episode of illness experienced.

In principle, the economic value of health benefits associated with improved levels of air quality could be measured as the public's willingness to pay to secure such improvements. Willingness to Pay (WTP) is an indicator of the strength of one's preferences for environmental quality and is influence by several factors including individual income, gender, cultural preferences, education or age. Cropper and Freeman (1991) show that Willingness to Pay (WTP) for small changes in air quality can be estimated through blending epidemiological evidence with individual Willingness to Pay (WTP) to avoid illness figures. The analysis in this part is developed on similar lines, based on the theoretical model formulated by Harrington and Portney. However, in contrast to the basic model, Willingness to

Pay (WTP) is estimated from the production function on the basis of mitigating activities and other socio-economic variables. An attempt is also made to estimate Willingness to Pay (WTP) directly by stated preference approach from a Contingent Valuation survey.

So far we have explained, the major theoretical approaches developed by economists to estimate the monitory values related to the impact of air pollution on human health. We shall now turn to the discussion of some of the major empirical studies on the subject in order to highlight the major findings and to discuss how these analysts have solved various estimation problems.

2.1.2 Empirical Studies on Valuation of Health Effects

There are several empirical studies in literature discussing the relationship between industrial air pollution and human health. These studies in general have attempted to estimate economic values of reduced morbidity and mortality due to air pollution. As mentioned earlier, factors affecting morbidity have been valued using two methods - Production Function and Contingent Valuation approaches. Both these approaches use willingness to pay (WTP) as a measure of reductions in morbidity.

Mitchell and Carson (1989) presented an annotated summary of more than one hundred Contingent Valuation surveys conducted between 1963 and 1987.Ostro

(1983) has estimated the increased risk of morbidity, using the Annual Health Interview Survey conducted by the National Centre for Health Statistics, U.S. Using two different variables – work days lost (WDL) and restricted activity days (RAD) as measures of morbidity, the author estimated the ordinary least square, tobit and logit regressions. In the OLS method, both WDL and RAD are shown to be related in a positive and significant way to measure morbidity. Similar results were also obtained in tobit and logit regressions.

Harrington and Portney (1987) hypothesized cost of illness as the lower bound to willingness to pay for the change in illness. He estimated that the mean willingness to pay for 'symptom reduction' is usually three to four times higher than the traditional cost of illness. Berger *et al.* (1987) reported mean WTP of $ 27 to eliminate a day of sinus congestion, compared with an average cost of illness of $ 7. The corresponding figures for throat congestion are $ 44 and $ 14 respectively.

Farber and Rambalsi (1993) used a Contingent Valuation (CV) approach to estimate willingness to pay (WTP) for ambient air quality improvements in East Baton Rouge, Louisiana. The authors attempted to estimate Willingness to Pay (WTP) to obtain the benefits for attaining Environmental Protection Agency, US ozone standards. The question was phrased in terms of the value that people placed on the assurance that no "un-healthful" days occurred. Estimated annual median and mean Willingness to Pay (WTP) values were $94 and $191 per person per year (in1991 US dollar terms) for assurance that ozone levels would not become 'un-healthful' on any day. Loehman, Park and Boldt (1994) also used a Contingent Valuation (CV) approach to value the benefits associated with improved air quality in the San- Francisco Bay Area. In this study, visibility and health effects were detailed as the primary benefits of cleaner air. Using open-ended / payment card in an in-person interview the authors attempted to capture WTP, had the respondent moved from one identified air quality 'state' to another. Average estimates of willingness to pay to avoid a decline in both health and visibility effects ranged from $6 to $73 per month (in1980 US dollar terms). Results of further statistical analysis by these authors confirmed that Willingness to Pay (WTP) estimates were sensitive to the wording of the Contingent Valuation (CV) questions, and that both socioeconomic variables and initial health-state had an impact on the magnitude of the willingness to pay estimates. In India, Abu backer (1994) studied the impact of industrial pollution on human health due to cement industries in Thiruchirappilly district in Tamil Nadu. Parikh et. al (1994) studied the health effects of air pollution in Mumbai[30].

Lang (1995) in her analysis of Canadian air quality policy derived an estimate of WTP for avoided hospital admissions for both respiratory and cardiac cases. Her estimate was based on data from the Canadian Institute for Health Information, and information on average weekly earnings. The hospital charges provided by the

[30] See footnote number 3 in first chapter.

Canadian Institute for Health Information were multiplied by a factor of 2 to reflect WTP to avoid pain and suffering. Lang's central estimates for avoided respiratory and cardiac admissions are approximately $5,700 and $7,200 respectively.

The paper by Chesnut, Ostro and Vadakan (1997) focused on the benefits to human health through reductions in particulate matter. The authors summarized the results of a set of health effects and economic valuation studies conducted in Bangkok, Thailand, concerning particulate matter air pollution. Comparing the willingness to pay (WTP) values of Bangkok with U.S. estimates, this study found that Bangkok residents were willing to pay a higher share of their income to protect their health. A plausible explanation provided for this result was that health might be seen as a basic necessity like food and shelter. Similar comparisons were made by Alberini and Krupnick (1997) for Los Angeles and Taiwan. Daily records from diary type epidemiological study were used to fit logit equations to predict the probability of experiencing minor acute respiratory symptoms. It was found that the rate at which illness were reported followed the fluctuations in PM_{10} levels but was unaffected by ozone concentrations. Illness rates were poorly predicted when the corresponding equation was estimated in a similar study conducted in Los Angeles. The authors argued that perceptions of illness and other cultural factors had played an important role in determining willingness to pay (WTP).

A similar study was conducted by Cropper et al. (1997) relating levels of particulate matter to daily deaths in Delhi, India, between 1991 and 1994. This study concluded: (a) the impact of particulate matter on total non-trauma deaths in Delhi was smaller than effects found in the United States, (b) the impacts of air pollution on deaths by age group might be different in developing countries than in the United States, where peak effects occurred among people aged sixty-five and above. In Delhi, peak effects occurred between the ages of fifteen and forty-four, implying that a death associated with air pollution causes more life-years to be lost.

Aunan, Patzay, Aaheim and Seip (1998) conducted a study to assess the cost and benefit of the implementation of a specific energy saving program in Hungary. They considered the possible reduced damage to public health, building materials and agricultural crops that might be obtained from reducing emissions of important air pollutants and also how the program contributed to reduced emissions of greenhouse gases. The benefits were estimated using monitoring and recipient data from urban and rural areas in Hungary, supplemented by exposure-response functions and valuation estimates from western studies. Their analysis indicated that the benefits from lower levels of pollutants reduced prevalence of chronic respiratory diseases and the estimated risk of air pollution attributed to excess mortality was around six percent. The estimated annual benefit of improved health conditions exceeded the investments needed to implement the program. In addition there were significant benefits due to reduced replacement and maintenance costs for building materials.

Alberini and Krupnick (1998) conducted an empirical study that recorded daily health status for over 900 residents of three urban areas in Taiwan. The study provided evidence that PM_{10} promoted new episodes of illness. The study concluded that the extrapolations from studies of other countries were inadequate for predicting benefits of reduced pollution levels. Health Impacts form a significant portion of the damage costs from air pollution. Navrud (1998) from a Norwegian Contingent Valuation Survey show that the common respiratory symptom days and asthma attacks were valued more in Norway than in the US. The difference between the US and Norwegian values can be explained by improved contingent valuation surveys and sample designs and different preferences in Norway.

A combined health risk assessment, cost-effectiveness analysis, and benefit-cost analysis were undertaken for direct particulate emissions from 29 stationary source polluters in the city of Volgograd, Russia by Larson et al.(1999). Annual particulate-related mortality risks from these stationary sources were estimated to be substantial, with estimates in the range of 960- 2,667 additional deaths per year in this city of one million. For several emission reduction projects, the cost-per-life saved was estimated to be quite low. The total net benefits to the city for implementing five of the six identified projects, led to roughly a 25 percent reduction in mortality risk.

Thanh and Lefevre (2000) applied the impact pathway approach (IPA) to estimate hea th impacts and corresponding damage costs of sulfur dioxide (SO_2) and particulate matter (PM_{10}) from four power units which used lignite, oil, natural gas, and coal at four locations in Thailand. The results showed that the damage cost related to health effects of electricity generation in Thailand was relatively small, ranging from 0.006 U.S. cent to 0.05 U.S. cent per kilowatt-hour (in 1995 dollars).

During the last decade, a number of quantitative epidemiological studies of specific diseases had been done in developing countries for the estimation of the total burden of disease (mortality and morbidity) due to use of solid fuels in adult women and young children. The study by Smith (2000) evaluated the existing epidemiological studies and applied the resulting risks to more than three-quarters of all Indian households depending on such fuels. Sufficient evidence was available to confidently estimate risks for acute respiratory infections (ARI), chronic obstructive pulmonary disease (COPD) and lung cancer. Estimates for tuberculosis (TB), asthma, and blindness are of intermediate confidence. Estimates for heart disease have the lowest confidence. Quantitative evidence was currently insufficient to estimate the impact of adverse pregnancy outcomes (e.g., low birth weight and stillbirth). The resulting conservative estimates indicated that some 400-550 thousand premature deaths can be attributed annually to use of biomass fuels in these population groups. Using a disability-adjusted lost life-year approach, it totals 4-6% of the Indian national burden of disease, placing indoor air pollution as a major risk factor in the country.

Alberni and Krupnick (2000) compared cost-of-illness (COI) and willingness-to-pay (WTP) estimates of the damages from minor respiratory symptoms associated with air pollution, using data from a study in Taiwan in 1991-92. A Contingent Valuation survey was conducted to estimate willingness to pay (WTP) to avoid minor respiratory illnesses. Health diaries were analyzed to predict the likelihood and cost of seeking relief for symptoms and of missing workdays. As predicted by estimates, WTP exceeded by 1.61 to 2.26 times, depending on the pollution levels. An important study on water pollution was done by Dasgupta (2001) in Delhi. The analytical focus was on a model of household health production function to estimate the value placed on safe drinking water by the households in the surrounding areas of Delhi. This study looked at the valuation of water as an economic resource in the context of a low income, infrastructurally disadvantaged urban household. Two alternative exercises were conducted to assess the impacts of both the quantity and quality of water being accessed and consumed by households. An objective assessment of the damage was made by looking at the health costs borne by households reporting diarrhea illness by adopting a health production function approach.

An alternative subjective assessment was made by conducting a Contingent Valuation exercise for these households. Subsequently, the study investigated the differences in the results between value judgments and damage assessment as revealed by the health costs approach. The study was based on a primary survey of households in urban Delhi. Primary data were collected through survey instruments from a sample of 6003 households distributed across 14 localities and 23 colonies. The estimated model was used for deriving the estimates of predicted probability of observing illness in each household of the sample. This probability value was used for estimating the cost of illness of households. The sum of treatment cost and wage loss due to illness for a representative household was given as Rs. 71.43 for a 15 day period during the peak time of diarrhea illness (May and June). The annual cost of illness estimated by taking into account the variation of incidence of illness over the months was obtained as Rs. 1094.31 for a representative household. This annual cost of illness might be interpreted as a representative household's willingness to pay for the improved drinking water quality.

Mark Dickie and Shelby Jerking (2002) have given a beautiful explanation for the estimation of willingness to pay (WTP) for reduced morbidity. They used household production function approach developed by Grossman (1972) Courant and Porter (1981), and Bartick (1988).

Contingent Valuation method was applied to obtain the values for avoided morbidity (Loehman *et al* , 1979, Loehman and De, 1982, Dickie *et al.*, 1997, Alberini *et al.*, 1997, Stale Navrud,1998; Alberini and Krupnick, 1998; 2000; Dickie and Ulrey, 2001). Ana Maria Ibanez and Mc Connell (2001) have studied economic costs of morbidity from acute respiratory illness in Bogotá, Colombia. Their purpose was to estimate WTP for a reduction in respiratory morbidity.

Measures of the value of reduced morbidity associated with environmental improvements must take into account the variety of ways in which people can benefit from reduced incidence of diseases. Theoretical and empirical works for obtaining monetary values for improvement in health, reviewed above, can be categorized as observed behaviour and stated preference methods. Developing the health benefits of improved air quality are usually obtained by combining epidemiological evidence linking pollution levels to health outcomes with the value of avoiding such outcomes. However, very few studies estimating willingness to pay have been conducted in developing countries. Growing concerns about air pollution and health in developing countries will increasingly need such quantitative estimates. As the empirical review above reveals, the extrapolations from studies of other developed countries are inadequate for predicting benefits of reduced pollution levels. Original valuation studies are needed in countries with cultural differences to US and Europe. The present study hence presents a simple model similar to Harrington and Portney, aiming to estimate willingness to pay through observed behaviour and stated preference methods. A matrix showing key features of some air pollution – health related studies is given in annexure 2.2 at the end of this chapter.

2.2. Review on Valuation of Residential Property Value Changes

Land value has received extensive research attention in neo-classical economic frame work. It is because, land unlike other factors simultaneously perform many public and private functions[31] (Xu, Feng, *et.al.*, 1993). This, along with the advances in economic theory and regression techniques, paved the way for numerous enquiries in which land values were attributed as a function of various factors such as presence of building, distance to town and likewise. Hence the hedonic theory hypothesised residential property price as a function of various structural, neighbourhood and environmental variables. Environmental characteristics, such as air pollution, affect residential property value and as a result, the household preferences on different properties vary, some even reaping an economic surplus. This variation in benefits due to reduced air quality provides the basic idea of hedonic model. The following sections review theoretical improvements and its empirical applications.

2.2.1 Theoretical Model and Conceptual Issues.

Economic theory had long recognized that the productivity of land differed across sites. Ronald Ridker (1967) was the first economist, who attempted to use residential property value data as the basis for estimating the benefits of changes in

---

[31] It is a factor of production used to produce income streams; it is space that produces amenity services; it is a thing of value which is identifiable and fixed in place; and so it is easily taxed.

environmental quality, such as air pollution[32]. Since the publication of Ridker's article (Ridker and Henning, 1967) an extensive literature had developed to interpret the data on air pollution and property value. The basic principle of this model is that, for many environmental goods, it is often possible for individuals to choose their level of consumption through their choice of related market goods. For example, one could consider the levels of air quality in the decision to purchase a residential property value (Anderson and Crocker, 1971; Schanare 1976). In a decision to buy a residential property, there is an 'implicit market' in environmental quality, and the demand for non-market environmental good, such as air pollution would contribute to observed prices and consumption of market goods.

Rosen, (1974), provided a theoretical model of hedonic regression. The Rosen model assumed that various characteristics of a differentiated product could be represented by a vector, $z = (z_1, z_2 ..... z_n)$. Its sales price (P) was represented as a hedonic function, of vector z. i.e., $P = p(z)$. The hedonic price schedule in the market could then be estimated by considering the behaviour of the consumers and firms. Consumers differ according to socio economic characteristics. A typical

[32] If the land market were to work perfectly, the price of a plot of a land would equal the sum of present discount streams of benefits and costs derived from it. If some of its costs rise, (for example, if additional maintenance and cleaning costs are required) or if some of its benefits fall (for example, if one can not see mountains from the terrace) the property will be discounted in the market to reflect people's evaluation of these changes. Since air pollution is specific to locations and the supply of locations is fixed, there is less likelihood that the negative effects of pollution can be significantly shifted to other markets. We should therefore expect to find the majority of effects reflected in this market, and we can measure them by observing associated changes in property values' [*Quoted in* Freeman , M., 1979a].

consumer gets satisfaction from the consumption of the characteristics of the differentiated product and a composite good 'x' by maximising his utility function subject to budget constraint, income. The first order condition for this optimisation problem requires that the marginal rate of substitution between one of the characteristics and the composite good be equal to the marginal price of the characteristic, $\partial P/\partial zi$. Rosen represented consumer's actions with a bid function, which represents consumer's willingness to pay for the product with characteristic 'z'. In equilibrium, the marginal bid function is equated to the marginal price. This procedure is followed in most empirical applications.

Some economists (Mailer, 1977; Freeman, 1979) had raised questions regarding the application of Rozen's model. First of all, regarding the reasonability of the assumption that the market for a differentiated product, such as, reaching equilibrium and the second was concerned with the versions of the differentiated product varying enough that the price function and the bid and offer functions could be assumed to be continuous. A number of variants of the original model have developed in connection with the nature of good valued and it's applications. Some of the environmental hedonic studies assumed that the markets are segmented[33] according to, income, race, accessibility, geographical variations and

[33] Freeman (1979b) defined a market as segmented if the segments have different hedonic price functions. This situation is possible only if a barrier prevents the purchases in one segment from participating in the other segment. Market segmentation between cities occurs if information and moving costs between cities are high.

other environmental variables.

Halvorsen and Pollakowski (1981) proposed a highly general flexible functional form called the quadratic Box-Cox. Spitzer (1982) provided an overview of several estimation methods that could be used with Box-Cox transformation. Cass and Mendelsohn (1985) suggested that the estimates of the coefficients of the environmental variables might be more reliable with simple functional forms. This was because, he argued, environmental variable played a minor role in determining the price.

McConnell and Phipps (1987) pointed out that there was a difference between marginal bid functions and ordinary inverse demand functions, which can be derived from the Hotelling-Wold theorem. The marginal rate of substitution functions are derived from $n-1$ of the first order equations, where n is the number of first order equations. Palmquist (1988) utilized the distance function to show that it is possible to normalize the marginal bid functions by income to obtain normalized compensated inverse demand functions.

Epple (1984, 1987) developed a closed form hedonic approach in which, the supply of the differentiated product is exogenous and is also distributed normally with no covariance. Giannias (1988) sought to relax some of these assumptions and use the model to estimate people's willingness to pay (WTP) for better air quality. He allowed non-zero off diagonal terms in the distributions of taste parameters and characteristic supply parameters. However, the closed form solutions to hedonic methods might not be considered valid for measuring environmental benefits because they are based on questionable assumptions.

Graves et al (1988) experimented with the data set from southern California to see how large the differences in the estimated parameters of the environmental variables would be when different functional forms were used. They identified variables as belonging to one of three categories: focus variables, free variables and doubtful variables. Focus variables are those that are of direct interest to the analysis at hand. Free variables are those which are not of direct interest to the analysis but which are known to be significant determinants of the dependant variable. Doubtful variables are those which might or might not be significant and/or for which uncertainty exists as to the expected sign of the parameters to be estimated. They subsequently devised a total of 16 different equation specifications and estimated the parameters for all 16 equations. In each case, all free and focus variables were entered into the equation. However, the 16 equations were differentiated by entering differing permutations of one, two, three, all or none of the doubtful variables into the regression equation. The authors selected the specification that introduced the least bias and the greatest estimated parameter stability. The analysis indicated that levels of air pollution are a highly significant determinant of house prices. However, with one specification the differences were negligible. Cropper, Deck and McConnell (1988) conducted Monte Carlo experiments to determine the accuracy of the marginal prices that were estimated with various functional forms of hedonic price equation. To obtain variations in true hedonic price function, they considered alternative functional forms and attributes for the utility functions of consumers as well as different utility function parameters, buyer characteristics and the housing characteristics. This study examined how errors in measuring marginal attribute prices vary with the form of the hedonic price function. Various forms of the hedonic function are estimated using equilibrium housing prices. Errors in estimating marginal attribute prices are calculated by comparing each consumer's equilibrium marginal bid vector with the gradient of the hedonic function.

Different arguments exist regarding the validity of environmental datasets used in housing hedonic equations. Almost all studies dealing with the effects air pollution on property values have used single objective measures of air pollution. Some researchers have begun to include more than one pollutant in their hedonic studies (Palm quest, 1982, and 1983, Garves *et. al*, 1988). Murdoch and Thayer (1988) found that when the distribution of visibility was included, it added to the explanatory power of the regression when compared with regressions using only the mean visibility. Contingent Valuations studies have been used for soliciting subjective measures of pollution and the contingent valuation results have been compared with hedonic studies (Brookshire et. al, 1982). Kerry Smith (1990) reviewed the conceptual basis for valuing environmental amenities and discussed travel cost recreation demand and hedonic property value models as strategies that rely on observed choice to measure use values for environmental resources. The importance of measuring non-use values is growing because people experience satisfaction from environmental resources without actually using them. Recent advances are described in using surveys within a Contingent Valuation framework.

Explicit estimates of compensating or equivalent variation have replaced measures of consumer surplus in many applied settings. A paper by Mason and John (1989) compared two widely used methods of making such estimates: so called "hedonic price" or implicit markets approaches and discrete choice methods based upon stochastic utility functions. Both techniques were applied to identical data sets in an extensive Monte Carlo simulation. The results were compared in terms of their accuracy in estimating consumer 'willingness to pay' for marginal and non-marginal changes in consumption.

Another optional is to estimate and inverse demand curves for the environmental quality variable [Garrod and Willis (1992) and Brookshire et. al (1981)]. This involved regressing calculated values of implicit prices against levels of the environmental variable and socio economic parameters. Brookshire et al. used implicit price and quality observations for fourteen neighbourhoods in the South Coast Air Basin of the Western USA. Community income was also included as an independent variable. Integrating under this function between two levels of environmental quality gave the total use benefits of an improvement from the lower to the upper level.

Allen, Marcus et al. (1995) examined implicit price differences of rental housing characteristics across various property types to measure whether determinants of rents were valued in the aggregate or separately. The results showed that hedonic price functions was not identical across property types which suggested that ordinary least squares was not the appropriate estimation technique when modelling the implicit prices for an aggregate rental market. The study by Serim and Seung Jun (1997) demonstrated that the important part of exploring the proper functional form of the hedonic price model would include investigating a dissimilar and unique hedonic price structure when the hedonic price model is applied to different housing markets. They made adjustments to the usual technique by incorporating the regional and cultural settings of the region.

The hedonic regression models have been used for the purpose of estimating the influence of environmental good (or bad) on the price of housing. The theoretical hedonic model developed by Rosen (1974) proved invaluable to researchers in the field. Freeman (1974) and Small (1975) were the first to show that the hedonic equation could be used to measure peoples marginal willingness to pay for an environmental improvement. Individuals could choose level of consumption of local public goods through their choice of the jurisdiction to reside in. If air quality varied in different areas, individuals might choose their exposure to air pollution through their location choices. The demand function for public goods such as air quality is estimated through a two step procedure in which, the implicit price is first estimated by the application of the hedonic price technique and then these prices are regressed against the observed quantities to estimate the demand function itself. It is generally accepted in literature that the choice of functional forms in hedonic regression models are likely to be empirically determined.

2.2.2 Empirical Review

The hedonic property approach seeks to explain the value of a commodity as a bundle of variable characteristics. The most common application of hedonic price model is to value people's willingness to pay for housing. Rather than explaining willingness to pay, the more appropriate approach is to assume that the coefficients of the estimated hedonic price function reveals the preference structure for the good's attributes and by using them to derive the implicit price for a change in the given attribute. (Garrod. G 1999).A numbers of empirical attempts have been made to value welfare reductions in property purchase due to environmental change.

Ridker (1967) and Ridker and Henning (1967) provided the first empirical evidence that air pollution affects property values by regressing median census trade property values on a measure of sulphate air pollution. Following this seminal work, a number of theoretical and practical interpretations were observed on pollution property relationship. Harrison and Rubinfield (1978) measured the marginal WTP as a percentage of income for an improvement in air quality at designated high levels of nitrogen oxides. They concluded that home buyers would be willing to pay up to 19 percent of their yearly income for a given improvement in air quality.

Nelson (1980) reviewed a number of empirical studies on the effects of air craft noise on property values using cross-sectional hedonic property methods. Results suggested that a unit reduction in Noise Exposure Forecast (NEF) indicator would result in a 0.51% appreciation in property values. Harrison and James (1984) estimated the benefits of cleaning up hazardous waste sites using a methodology based on housing price differences. They estimated households' implicit willingness to pay to locate, farther from hazardous waste sites. The empirical results showed the willingness to pay for the cleanup of three sites in the Boston area (in 1980 dollars) and these benefit estimates ranged from $3.6 million to $17.4 million.

In a review of a number of air pollution hedonic price model studies, Pearce and Markandya (1989) demonstrated that a 1 percent increase in sulphation levels resulted in a fall in property values between 0.06 and 0.12 percent, a 1 percent increase in particulates lowered property values by 0.05 to 0.14 percent, while a 1 percent increase in a variable, which picked up a number of measures of air pollution was associated with a 0.09 to 0.50 depreciation in property prices.

A hedonic price study of the effect of airport noise on property prices by Levesque (1994) uncovered relationships with the number of events that affected a location and the mean and variance of the loudness of the events. The results suggested that hedonic price models that include cumulative energy noise measures, such as the Noise Exposure Forecast, do not perform as well as predicted models.

In a pioneering work on property valuation in India, Parikh et al. (1994) estimated a hedonic property price equation and made certain illuminating observations on the effects of air pollution on property values in Mumbai. The data was taken from 'the metropolitan household survey' of Bombay Metropolitan Region Development Authority. The rent values reported by the households were used for analysis along with neighbourhood, structural and ethnic characteristics. The concentration of SPM in a given locality was taken as a measure of air quality. The results showed that air pollution affected the rent negatively in the hedonic price model, that is, an 8 percent drop in rent per a 100 p.p.m increase in SPM. The mean value of SPM was greater than the Indian and World Health Organisation standards. The hedonic price model model predicted positive benefits for the urban dwellers in Bombay for a reduction in SPM from the currently observed levels to the national air quality standards in India.

In their analysis, Kerry Smith and Huang, Ju Chin (1995) reported the results of a statistical summary of estimates of the marginal willingness to pay for reducing particulate matter from hedonic property value models developed between 1967 and 1988. Results from ordinary least squares and minimum absolute deviation estimators considered the effects of market conditions and the implementation procedures for hedonic models. The inter-quartile range for these estimated marginal values (measured as a change in asset prices) lay between zero and $98.52 (in 1982-84 dollars) for a one-unit reduction in total suspended particulates.

Figueroa (1996), used a hedonic price model to estimate the effect of air pollution on house prices in Santiago and also to estimate the willingness to pay (WTP) for a program that reduced air contamination by 50 percent. The data consisted of 992 observations containing market prices for houses and their characteristics. The average willingness to pay for the air quality improvement program was estimated as $567,000 (US $1.626) and the aggregated willingness to pay for Santiago as almost 600 billion pesos (US $1.7 billion). Tiwari, Piyush; Parikh, Jyoti (1997) estimated the demand function of housing for Bombay Metropolitan Region in a two step econometric analysis. The first step estimated the hedonic price index for different regions in Bombay, and in the second step the demand for housing was estimated as a function of economic and household characteristics. The results indicated that housing demand was inelastic with respect to income and price. The income elasticities for owners and tenants was around 0.33 and 0.38, respectively, while the price elasticities were 0.21 and 0.75, respectively, for owners and tenants.

In a hedonic study of rural residential house sales in south-eastern North Carolina to determine the effect of large scale hog operations on surrounding property values, Palmquist et al. (1997), found that proximity caused statistically significant reduction in house prices of up to 9 percent depending on the number of hogs and their distance from the house. The effect on the price of a house from opening a new operation depended on the number of hogs already in the area. Cheshire and Stephen (1998) provided estimates of the structure of demand for individual housing and neighbourhood characteristics and for land in two British cities. The authors estimated a hedonic price function and from this obtained the implicit prices of house attributes. These prices were used to estimate a demand system for each city. Estimates derived from this method, however, differ only slightly from those obtained using the conventional techniques. Several features of these estimates provided insights into the unusual characteristics of the British housing market, the effects of constraints imposed by land-use planning and the effects of changing income distribution on the structure of demand.

Chattopadhyay (2000) combined a new, large household-level data set with a two-stage hedonic-estimation technique to derive new estimates of willingness to pay (WTP) for reduced air pollution. The WTP estimates were found robust against functional-form specifications. Marginal WTP estimates for a reduction in particulate matter (PM_{10}) were found to be quite comparable with some previous estimates. Benefits of non-marginal changes exhibited consistently higher monetary returns in the case of PM_{10} than in the ease of SO_2, signifying that households dislike particulate pollution more than they do sulphur.

Using estimates from hedonic-price equations and residual-demand models, Taylor and Smith (2000) recovered firm-specific estimates of price mark-ups as measures of market power and used these mark-ups to estimate the implied marginal value for access to coastal beaches. The application involved rental price and occupancy data for several thousands of beach properties along a portion of the North Carolina coastline during the 1987 to 1992 rental seasons. Gayer et al. (2000) incorporated a Bayesian learning model into a hedonic framework to estimate the value that residents place on avoiding cancer risks from hazardous-waste sites. The results showed that residents' willingness to pay to avoid risks actually decreased after the release of the Remedial Investigation, suggesting that the information lowers the perceived levels of risk. This estimated willingness to pay implied a statistical value of cancer similar to the value-of- life estimates in labour market studies.

Hedonic property value models were often used to derive point estimates for identifying the relationship between environmental quality and property prices. Case studies carried out by Michael et al. (2000) derived implicit prices for nine measures of water clarity using hedonic property value models of lakefront properties in Maine. Results showed that water clarity variables based on different perceptions could result in differences in implicit prices, large enough to potentially affect policy decisions. Mahan et al. (2000) estimated the value of wetland amenities in the Portland, Oregon, metropolitan area using the hedonic property price model. Residential housing and wetland data were used to relate the sales price of a property to structural characteristics, neighbourhood attributes, and amenities of wetlands and other environmental characteristics. Environmental variables were distance to and size of wetlands, including distance to four different wetland types, open water, emergent vegetation, scrub-shrub, and forest. Results indicated that increasing the size of the nearest wetland to a residence by one acre increased the residence's value by $24. Similarly, reducing the distance to the nearest wetland by 1,000 feet increased the value by $436. Home values were not influenced by wetland type. An analysis of the demand for air quality in four cities in the United States was carried out by Zabel and Kiel (2000). The marginal prices of air quality were obtained from parameter estimates for the pollution variables in a hedonic house price model and the marginal willingness to pay (inverse demand) equations for air quality were estimated using these prices. In two of the four inverse demand equations for air quality, the own-good coefficient was negative and significant, while the income coefficient was positive and significant

2.3 Conclusion

There exist several dozen empirical studies interpreting the relationship between environmental amenity and property values. Empirical applications of hedonic approach have typically focused either on valuing marginal amenity changes, which required estimating only the hedonic price function or computing the short run benefits of non marginal amenity changes, which required estimating marginal bid functions. Estimation of bid function could encounter identification problems which are caused by the fact that the arguments of the marginal attribute bid function determine marginal attribute prices as well (Cropper and Oates, 1992). A variety of solutions were suggested in theoretical and empirical literature (James Brown and Harvey Rosen, 1982; Mendelsohn, 1984; Palmquest, 1984; Ohlsfeld, 1985). In the empirical studies, housing prices were regressed on the ambient air quality, which were negatively correlated with visibility. Most of the studies found significant negative effects of air pollution on housing prices, and thus provided indirect evidence that people were willing to pay for better air quality. Based on the theoretical model discussed in Freeman (1993) the current analysis attempted to estimate implicit prices for reduction in SO_2. A matrix showing key features of certain air pollution – property value related studies is given in annexure 2.3 at the end of this chapter.

Most of the studies listed above were based mainly on the experiences of industries of the developed countries while the nature of industrial pollution produced by the third world industries remains unexplored for long. In developing countries like India, air pollution has been consistently growing during the last few decades and is extremely complex. Policy makers have a tendency to borrow the principles and solutions offered by western economists to mitigate pollution in developing countries without examining in detail the possible local solutions to such issues. Since there are excellent surveys available on the health- property value-environment nexus, our survey is selective and brief. It is difficult to summarise the results of all the studies reported here because they cover a number of places, time periods, empirical techniques and model specifications. However, the basic evidence that comes from the review is that, health and property prices are affected by air pollution in general. The subsequent chapters are developed based on this assumption. This chapter also provides an insight for understanding the development of theoretical model and its strengths and weaknesses.

Annexure : 2.1

Major air pollutants and its health effects

Pollutant	Main characteristics	Principle health effects
Sulphur dioxide	Colourless gas with pungent odor; oxidizes to form sulphur trioxide, which forms sulphuric acid with water	Classed as mild respiratory irritant; mostt SO2 inhaled is absorbed in upper respiratory tract and never reaches lungs; penetrates when clings to particulate matter; aggravates respiratory diseases, including asthma, chronic bronchitis and emphysema; can result is reduced lung function, irritation of eyes, and possibly incrased mortality.
Nitrogen oxides	Mixture of gases ranging from colourless to reddish brown	Major role as a component in creation of photochemical smog; also has distinct effects apart from those associated with smog; has been shown to be toxic in experimental animals; some studies indicate NO_2 produces animal diseases that have human counterparts (emphysema, other lung diseases); study of school childrean in high NO_2 rears found that children contracted significantly more respiratory disease than children in control area; has been shown to aggravate respiratory and cardiovascular illness and chronic nephritis.
Particulate Matter	Any solid or liquid particles dispersed in atmosphere, such as dust, pollen, ash, soot, metals, and various chemicals; particles often classified according to size, as settleable particles (>50 microns), acrosols (<50 microns) and fine particulate (< 3microns).	Direct toxic effects or aggravation of the effects of gaseous pollutants; aggravation of asthma or other respiratory of cardio respiratory symptoms; increased cough and chest discomfort; increased mortality.

Source: Baumole W. J and Oates (1979) "Economics, Environmental policy, and the quality of life". Prentice Hall.

Annexure 2.2

A Summary of Air pollution - Health Related Studies.

Authors	Model activity	Data / location	results
Alberini and Krupnik (2000).	compare cost-of-illness (COI) and willingness-to-pay (WTP) estimates of the damages from minor respiratory symptoms.	Using data from a study in Taiwan in 1991-92.	Health diaries are analyzed to predict the likelihood and cost of seeking relief from symptoms and of missing work. As predicted by estimates, exceeding the latter by 1.61 to 2.26 times, depending on pollution levels. These ratios are similar to those for the United States, despite the differences between the two countries.
Thanh and Lefevre (2000)	Impact pathway approach (IPA) to estimate health impacts and corresponding damage costs of sulfur dioxide (SO2) and emissions of fine particulate matter (PM10) from four power units using different fuels (lignite, oil, natural gas, and coal) is applied.	Four locations in Thailand.	The damage cost related to health effects of electricity generation in Thailand are relatively small, but not negligible, ranging from 0.006 U.S. cent to 0.05 U.S. cent per kilowatt-hour (in 1995 dollars). Damage costs to the public health due to SO2 and PM10 emissions from electricity generation not only depend on fuel and generating technology but also depend strongly on power plant location.
Alberini and Krupnic (1998)	Estimating to WTP to avoid episodes of illness due to air pollution.	900 residents in Urban areas in Taiwan	The study provides evidence that PM_{10} promotes the beginning of new episodes of illness, but the results are less pronounced than earlier US studies. The study concludes that the extrapolations from studies of other countries are inadequate for predicting benefits of reduced pollution levels
Navrud (1998)	CVM to estimate damage costs of illness due to air pollution.	Norway and then compared to US.	Annual particulate-related mortality risks from these stationary sources are estimated to be substantial, with estimates in the range of 960- 2,667 additional deaths per year in this city of one million. For several emission reduction projects, the cost-per-life saved was estimated to be quite low. The total net benefits to the city of implementing five of the six identified projects, lead to

			roughly a 25% reduction in mortality risk.
Alberini, A Cropper, M.,et al (1995)	CVM to estimate Wtp in Taiwan for Avoiding Illeness	Individual sample of HH for Taiwan	Finds that Taiwanies WTP around $ 40 tp avoid an illness lasing 5.3 days and with 2.2 symptoms. Thsis is then compered to a Benefit Transfer.
Ostro B (1994)	Morbidity effects of air pollution include restricted activity days, out patient visits, hospital admissions, respiratory illness among childrean, Asthma ttack and respiratorty symptoms	Individual sample for Jakarta	Air pollution health damage for Jakarta come to some 220 dollar million a year or some 27 dollar percapita. Water pollution damage assumes 7000 diarrhoea related deaths per year. Improved water Quality and sanitation will reduce such deaths by 55 – 60 percent per annum, so thet 3800-4200 deaths could be avoided some 3 60000 less diarroheal episodes per years are estimated to saved by improved water quality.
Loehman, Park and Boldt (1994)	CV approach to value the benefits associated with improved air quality. The authors used in-person interviews with an open-ended / payment card format for their WTP question	San Francisco Bay Area	Average estimates of willingness to pay to avoid a decline in both health and visibility effects ranged from $6 - $73 per month (1980 US$). Results of further statistical analysis by these authors confirm that WTP estimates are sensitive to the wording of the CV questions, and that both socioeconomic variables and initial health-state have an impact on the magnitude of the WTP estimates.
Parihk and muraleedharan (1994)	Uses Dose- Response for health and Hedonic Property model for General Air Pollution Impact. Value of Statistical life is estimetd on the basis of Human Capital Approach	Individual sample from Mumbai	Workdays lost are are liked to Particulate Matter and linked particulate matter and cost are estimated using medical and hospital costs
Krupnick A, Harroson K et.al (1993)	Assessess potential benefits of improving SO2, SPM and lead emissions in Eatern Europe to EC levels. Mortality is valued by statistical life	Individual sample of Data from Centarl and Eaastern Europe	Nearly all health benefits accrue from Particulatecontrol low estimate of benefits are 1-4 percenet of GDP and middle range estimates are 4-12 percent
Farber and Rambalsi (1993)	CV approach to estimate WTP for ambient air quality improvements. The authors attempted to estimate WTP to obtain the benefits of attaining EPA ozone standards.	East Baton Rouge, Louisiana.	Estimated annual median and mean WTP values were $94 and $191 per person per year (1991 US$) for assurance that ozone levels would not become 'unhealthful' on any day.

Desvousges, Smith and Rink (1989)	Reduced for model describing dicrete choice monitor home for radon; no observed variation in price of monitoring. Probit model is used.	Controlled experiment involving public risk communication probgramme; panel study each of three towns in Maryland.	Prior knowledge of radon, discussion with friends and neighbours and intensive information programme positive determinants of likelihood of testing
Dickie and Gerking (1989)	Using House hold Production Function Model. extension to Gerking Stanley behaviour reflected in estimation of functions hypothesized to associated with air pollution.. Tobit estimator	Set of health symptoms hypothesized to be associated with air pollution;	Air pollution measures not significant
Smith and Desvousges (1986)	Reduced form model – undertake activity – purchase water filters boiled water, attend public meeting about contamination of water with hazardous subsistence. Probit model for discrete outcome for each action	Individual sample of HH for suburban Boston;	Attitudes important to purchase of filters and bottled water; news accounts and location in town with contamination incidents affect participation in public meeting
Gerking and Stanley (1986)	Household Production Function model for health Stock; single equation framework recognizing role of medical care; health treated as a choice variable. probit model to describe descrete outcome	Indidual sample for St. Luis;	Ozone a significant positive influence; Chronic health conditions also a positive determinat of likely hood of visiting of doctor

Annexure 2.3

A summary of the Air Pollution -Property Value studies.

Author	Variables	Functional form	Results
Zabel, J. E., and K. A. Kiel (2000)	American Housing Survey Data, air quality variables, Property value variables.	Linear	The marginal prices of air quality are obtained from parameter estimates for the pollution variables in a hedonic house price model, and the marginal willingness to pay (inverse demand) equations for air quality are estimated using these prices. In two of the four (inverse) demand for air quality equations, the own-good coefficient is negative and significant, while the income coefficient is positive and significant.
Gayer, T., J. T. Hamilton, and W. K. Viscusi (2000)	Cancer risks from hazardous waste sites, other socio economic and property value variables.	Bayesian learning model	Residents' willingness to pay to avoid risks actually decreases after the release of the Remedial Investigation, suggesting that the information lowers the perceived levels of risk. This estimated willingness to pay implies a statistical value of cancer similar to the value-of- life estimates in labor market studies.
Chattopadhyay, S. (1999)	Household-level data set with the two-stage hedonic estimation technique to derive new estimates of willingness to pay (WTP) for reduced air pollution. Air quality variables are Sulplhur and PM10.	Nested Logit Model	The WTP estimates are found robust against functional-form specification. Marginal WTP estimates for a reduction in particulate matter (PM-IO) are found to be quite comparable with some previous estimates. Benefits of nonmarginal changes exhibit consistently higher monetary returns in the case of PM-10 than in the ease of SO2, signifying that households dislike particulate pollution more than they do sulfur.
Cheshire, Paul; Sheppard, Stephen (1998)	Housing and neighborhood characteristics and for land in two British cities.	Linear	estimate a hedonic price function, and from this obtain the implicit prices of house attributes. These prices are used to estimate a demand system for each city. These perform well, and enable them to calculate price and income elasticities for each of the nondichotomous characteristics and for land.
Palmquist, Raymond B.; Roka, Fritz M.; Vukina, Tomislav (1997)	Structural and neighborhood variables. An index of hog manure production at different distances from the houses was developed.	Linear	It was found that proximity caused a statistically significant reduction in house prices of up to 9 percent depending on the number of hogs and their distance from the house. The effect on the price of a house from opening a new operation depended on the number of hogs already in the area.

Tiwari, Piyush; Parikh, Jyoti (1997)	Structural, neighborhood and environmental variables.	Demand function of housing for Bombay Metropolitan Region in a two step econometric analysis.	The results indicate that housing demand is inelastic with respect to income and price. The income elasticities for owners and tenants are around 0.33 and 0.38, respectively, while the price elasticities are 0.21 and 0.75, respectively, for owners and tenants. We also estimate income and price elasticities for different income classes. The paper concludes with policy prescriptions
Nelson (1978)	Particulates, Oxidents, Property 5 variables neighborhood 6 variables	Linear, semi-log, and long linear form, were tested,; semi-log and long linear forms gave best results, only the latter were reported	Particulate coefficient always significant in range 0.048-0.116; oxidant significant in range 0.007-0.019 at the mean an additional 0 $\mu g/m^3$ of particulars reduces values of mean property by 576-693$; at the mean an additional 0.01ppm of oxidants reduces value of mean property by $ 141-152
Harisson Rubinfeld (1978)	Mean concentration of nitrogen oxide and particulates calculated from dispersion model, Property 2 variables Neighborhood 10 variables	Exponential semi-log: log $MV = a0+a1NO_z^c$..Where c is an unspecified parameter. Best results obtained with c = 2	Separate equations run for each pollutant; each pollutants significant at 0.01 level; many alternative specifications employed; authors conclude that pollution coefficient is quiet sensitive to the specification of the hedonic housing value equation
B.Smith(1978)	Particulates computed from dispersion model, Neighborhood 9 variables	Linear	Individual site values fall by $430 – 510 per 10 $\mu g/m^3$ increase in particulates
Polinsky – Rubinfeld (1977)	Sulfation annual arithmetic mean, Particulates annual arithmetic mean, Property 2 variables Neighborhood 2 variables Income from derivation of open city model	Log-linear	Sulfation and particulates both included; owner equation coefficients on: Log S = -0.063a Log P = -.132b Rental equation coefficients on Log S = -.006 Log P = -.137b, They imply a "a composite elasticity " of about 0.2
Goodwin (1977)	Properly 3 variables neighborhood 23 socioeconomic variables Location: 21 accessibility and transportation variables	Linear Towns of Boston subdivisions classified as "little", "moderate" or "high" pollutant and	Pollution index variable negative and significant

		averaging times not specified	
Schnare (1976)	Particulate, Property 7 variables Neighborhood 11 variables Income as proxy for neighbourhood	Semi-log	Particulates negative and significant
Charlestown S. C Steele (1972)	SO_2 and particulates, Neighborhood 14 variables Income as a proxy for other neighborhood characteristics	Linear	Pollution variables had expected signs but were not significant at 0.05 level
Pittsburg Spore (1972)	Sulfation annual geometric mean and maximum monthly value by lead candle, Dustfall annual geometric mean and maximum monthly value, Property 3 variable Neighborhood 12 variables Income as a determinant of demand	Log-linear	Many alternative specifications with sulfation and dust fall both entering annual mean or maximum dustfall almost always significant at 0.05 level; dust fall coefficients (elasticities) generally in 0.092-0.149
Anderson-Crocker(1971b)	Sulfation annual arithmetic mean, Particulates annual arithmetic mean, Property 3 variables Neighborhood 2 variables Income on basis that each census tract is a submarket in equilibrium	Log-linear	Sulfation and particulates both included; best results with owner-occupied property value; coefficients on Log S = -.102 Log P = -.119; They imply a "composite elasticity" of .1-.2 ; at the mean an additional 10 $\mu g/m^3$ of particulates pus .1 $\mu g/100\ cm^2/day$ of sulfation reduces value of mean property by $300-700
Peckham (1970)	Sulfation one month average, Particulates arithmetic mean, Property 3 variables Neighborhood 3 variable Income as proxy for neighborhood characteristics	Linear and Log-linear	Sulfation in linear, the coefficient was $298 per 0.25 $\mu g/100cm^2/day$; the log linear coefficient 0.096; particulates significant only in the log form with a coefficient of 0.116
Crocker(1970)	Sulfation annual arithmetic	Log-linear	May equations with different specifications ; when S and particulates

	mean , annual arithmetic mean Property 6 variables Neighborhood 4 variables Income based on interpretation of housing price equation as a bid function		are both included , coefficient on particulates usually negative4 and significant in range 0.2-.5; S often positive and usually not significant; when only one pollutiojn variable included, it was always negative and significant ; elasticities imply at the mean an additional 10 μg/m^{3}of particulates plus 1 ppb of SO_2 reduces value of mean property by $350-600
Hamilton Zerbe (1969)	Sulfation annual average by lead, Property 5 variables Neighborhood 8 variables Income as proxy for neighborhood characteristics	Both linear and log-linear	Sulfation , linear form coefficients ranged from $200-$450 per 0.25μg/100 cm^2/day; log linear coefficients 0.061-0.121 for Toronto; for Hamilton, linear coefficient ranged $ 580-882, and the log-linear estimate was 0.081

Chapter 3

Major Sources and Nature of Air Pollution in Cochin Industrial Agglomeration

As indicated in the introduction, air pollution is one of the most important problems affecting the overall health of human beings in both developed and developing countries. Air pollution is an inevitable outcome of industrial operations, combustion of fuels for heating and energy production, solid waste disposal and other mobile sources including motor vehicles. In each of these categories, different varieties of air pollutants like gaseous pollutants, odours, and suspended particulate matter (SPM) such as dust, fumes, mist, and smoke harmful to the society are detected. The major air pollutants most commonly found, other than particulates are sulphur dioxide, carbon monoxide, nitrogen dioxide and hydro carbons. The concentration of these substances in and near the urban areas causes severe pollution to the surroundings. The objective of this chapter is to provide a detailed description of the major sources and the nature of air pollution in the study area. This chapter begins with a brief note on the status of air pollution in India and Kerala in sections 1 and 2 respectively and then introduces a detailed account of the main sources and the status of air pollution in and around Cochin industrial agglomeration in section 3. Section 4 provides a brief summary of major findings of this chapter.

3.1 Air pollution : The Indian Scenario

Air pollution in India has been the by-product of both modern industries and indoor activities using solid fuels such as wood, coal, dung, charcoal and crop residues etc. for cooking and heating purposes. A Government of India document prepared for the United Nations Conference on the Human Environment in 1972 admitted that "the present total emission of Carbon Monoxide, Sulpher Dioxide, Nitrogen Oxide, Particulates, Organics etc. are much larger from burning of firewood, cattle dung, vegetable waste products, refuse etc" (Centre for Science and Environment, 1982). It is estimated that about 82 percent of the Sulphur Dioxide emissions and 39 percent of Nitrogen Oxide emissions are produced within households. About 96 percent of particulate matter emissions in the country also come from the household sector (Indira Gandhi Institute of Development Research, 2000). The rural population in India use a substantial quantity of non commercial fuel, such as crop residue, animal dung or wood. Smith (1998) observed that usage of wood, dung etc for cooking adds to causes severe indoor pollution and results in premature deaths of 4,10,000 to 5,70,000 every year. In addition, he observed that in each death, there are about 6 person-years of illness in the population. Women and children and Senior citizens are found to be the most affected due to indoor air pollution.

3.1.2 Major Air Pollutants and Air emission Accounts for India

Industrialization and urbanization have resulted in a profound deterioration of India's air quality. Mega cities of India are among the most polluted in the world, with concentrations of a number of air pollutants much higher than WHO recommended levels. The capital city, New Delhi, for instance, is one of the top ten most polluted cities in the world. Surveys indicate that in New Delhi the incidence of respiratory diseases due to air pollution is about 12 times the national average. Similarly, it is observed that while India's gross domestic product has increased 2.5 times over the past two decades, the vehicular pollution has increased eight times and pollution from industries has quadrupled (Energy Information Administration, 2001, http://www.eia.doe.gov/).

In Urban India, transport sector is the major contributor to pollution producing 74 percent of carbon monoxide and all the lead emitted. The number of vehicles in India has been steadily increasing leading to a concurrent increase in pollution. The vehicular emission load in twelve major Indian cities, estimated 1994 was 3596.8 tones per day which formed a significant part of total air pollution load in theses cities. Industries, power plants and burning of solid waste also add to the pollution loads. Around 1551 medium and large industrial units in the country in 17 highly polluting industrial sectors have been identified as polluting by the Central Pollution Control Board. Of these about 77 percent are predominantly water polluting, 15 percent are predominantly air polluting and 8 percent are both air and water polluting industries. The industrial sector in 1995 contributed 2 million metric tonnes of pollutants.[1]

The major air pollutants of possible concern are identified as suspended particulate matter, carbon monoxide, oxides of nitrogen, sulphur dioxide, mercaptans from oil refineries, heavy metals from smelters, fluorides from aluminium smelters, iron oxides from steel works, dust/particulate matter from cement works, disposal of solid wastes, hydro carbons, oxidants, ozone, lead etc. These pollutants emerge mainly from domestic heating, cooking, industrial boilers and power plants, manufacturing industrial processes and transportation. A detailed classification of these air pollutants by source of economic activity is given in Table 3.1 below.

---

[1]Pollution monitoring has been undertaken in India by the Central Pollution Control Board (CPCB) with the help of various State Pollution Control Boards. They also receive assistance from a number of sponsored autonomous research institutes. The National Ambient Air Quality Monitoring (NAAQM) network is operated through the respective State Pollution Control Boards, the National Environmental Engineering Research Institute (NEERI), Nagpur, and also through the CPCB. Apart from conventional parameters, NEERI also monitors special parameters, like Ammonia (NH3), Hydrogen Sulphide (H2S), Respirable Suspended Particulate Matter (RSPM) and Polyaromatic Hydrocarbons (PAH).

Table 3.1

Principal Sources and Air Pollutants of Possible Concern in Urban Areas

Type of Sources	Fuel	Main Pollutants
Domestic Heating, Cooking	Wood, Peat, Biomass etc.	Suspended Particulate Matter, Carbon Monoxide, Oxides of Nitrogen
	Coal	Suspended Particulate Matter, Sulphur Dioxide, Carbon Monoxide, Oxides of Nitrogen
	Light Oil, Gas	Oxides of Nitrogen, Sulphur Dioxide
Industrial Boilers and Power Plants	Coal , Heavy Oil	Oxides of Nitrogen, Sulphur Dioxide, Suspended Particulate Matter
Manufacturing Industrial Processes		Specific pollutants related to nature of process. E.g, Sulphur dioxide and Mercaptans from oil refineries, Heavy metals from smelters, Fluorides from Aluminium smelters, Iron oxides from steel works, Dust/Particulate matter from cement works and disposal of solid wastes etc.
Transportation	Gasoline	Carbon Monoxide, Oxides of Nitrogen, Hydro Carbons, Oxidants, Ozone, Lead
	Diesel	Suspended Particulate Matter, Oxides of Nitrogen, Odour, Sulphur Dioxide

Source: AAQM data, CPCB, New Delhi (2000)

The percentage distribution of air emission accounts for India for the year 1989-90 is summarised in table 3.2 and represented in figure 3.1

Table 3.2

Percentage Distribution of Air Emission Accounts for India for the year 1989-90

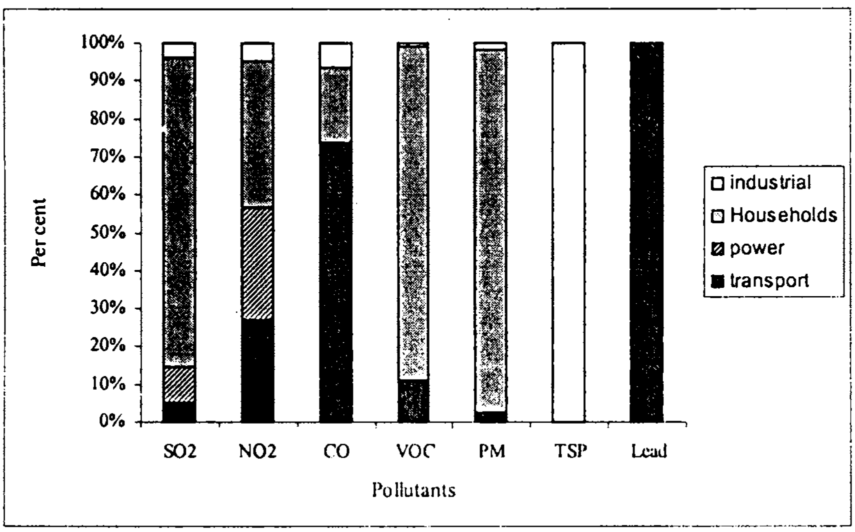
Pollutants (000's tonnes)	Households	Transport	Industry	Power
SO_2	306	565	4898	243
NO_2	695	765	993	126
CO	1617	0	426	144
VOC	751	0	5803	69
PM	206	0	7770	131
TSP	0	0	0	68
Lead	16	0	0	0

Source: Parikh and Parikh (1999)

The table reveals that all sectors are responsible for the emission of major pollutants, SO_2, and NO_2in the country. CO, VOC and PM are emitted by all sectors other than transport sector. However, major contributors of TSP and Lead are power sector and households respectively.

Figure 3.1

Air Emission Accounts for India for the year 1989-90



Source: Parikh and Parikh (1999)

3.1.3 Ambient Air Quality Standards in India

As in the rest of the world, India also witnessed dramatic change in environmental concerns, during the last two decades[2]. In the year 1994, Central Pollution control Board laid down the Ambient Air Quality Standards of various pollutants for industrial and residential sensitive areas. These standards provide the basis for protecting the public from adverse effects of contaminants of air that are likely to be hazardous to human beings, vegetation, animals and national heritage. The pollutants monitored include Sulphur dioxide (SO2), Nitrogen dioxide (NO2) and Suspended Particulate Matter (SPM) besides the meteorological parameters, like wind speed and direction, temperature and humidity. The most commonly found air pollutants are particulates, sulphur dioxide, carbon monoxide, nitrogen dioxide and hydrocarbons. The Central Pollution Control Board monitor three important (suspended particulate matter, sulphur dioxide and oxides of nitrogen) among them, Air quality with respect to Suspended Particulate Matter (SPM) is available both for residential and industrial areas in selected locations. Air quality with respect to

---

[2] Air Pollution first attracted national attention in India, in 1972 when the Government announced plans to build an Oil refinery in Mathura just, 40km away from the Taj Mahal. The threat to the Taj Mahal is one of the most documented air pollution case study in India. In December 3, 1984, a holding tank at the Union Carbide pesticide factory in Bhopal, India, overheated and burst, releasing a highly toxic gas. The state government of Madhya Pradesh reported that approximately 3,800 persons died, 40 persons experienced permanent total disability, and 2,680 persons experienced permanent partial disability. Studies by India's Council of Medical Research indicate that severe injury to the lung is limited to a small percentage of the population and there is no serious residual eye disease. Besides the leaves of Bhopal's trees turned black as a result of this tragedy.

Suspended Particulate Matter, Suphur dioxide and Oxides of Nitrogen is further classified into four classes [3]

The National Ambient Air Quality Standards based on Annual Mean Concentration of SO2, NO2 and SPM for India published by the CPCB are given in table 3.3.

---

[3] Designated by 4 classes- low, moderate, high and critical. In residential areas if the incidence of SPM is below 75 $\mu g/m^3$, between 75-140 $\mu g/m^3$, and between 140-210 $\mu g/m^3$, then these areas are designated as zones affected as low, medium and high respectively. If the value is greater than 210 $\mu g/m^3$, then the area is said to be critically affected. In Industrial area, these values are below 180 $\mu g/m^3$, 180-360 $\mu g/m^3$, 360-540 $\mu g/m^3$, and greater than 540 $\mu g/m^3$ respectively.

Sulphur Dioxide: Air quality with respect to suphur dioxide is designated by four classes- low, moderate, high and critical. In residential areas, below 30 $\mu g/m^3$ (low), 30-60 $\mu g/m^3$ (moderate), 60-90 $\mu g/m^3$ (high), and greater than 90 $\mu g/m^3$ (critical) respectively. In Industrial area, there values are below 40 $\mu g/m^3$, 40-80 $\mu g/m^3$, 80-120 $\mu g/m^3$, and greater than 120 $\mu g/m^3$.

Oxides of Nitrogen The designated classes and maximum permissible limits of oxides of nitrogen are same as that of sulphur dioxide.

Table 3.3

National Ambient Air Quality Standards (NAAQS)

Pollutants	Time-weighted average	Concentration in ambient air			Method of measurement
		Industrial Areas	Residential, Rural & other Areas	Sensitive Areas	
SulphurDioxide (SO_2)	Annual Average*	80 $\mu g/m^3$	60 $\mu g/m^3$	15 $\mu g/m^3$	- Improved West and Geake Method - Ultraviolet Fluorescence
	24 hours**	120 $\mu g/m^3$	80 $\mu g/m^3$	30 $\mu g/m^3$	
Oxides of Nitrogen as (SO_2)	Annual Average*	80 $\mu g/m^3$	60 $\mu g/m^3$	15 $\mu g/m^3$	- Jacob & Hochheiser Modified (Na-Arsenite) Method
	24 hours**	120 $\mu g/m^3$	80 $\mu g/m^3$	30 $\mu g/m^3$	- Gas Phase Chemiluminescence
Suspended Particulate Matter (SPM)	Annual Average*	360 $\mu g/m^3$	140 $\mu g/m^3$	70 $\mu g/m^3$	- High Volume Sampling, (Average flow rate not less than 1.1 m3/minute).
	24 hours**	500$\mu g/m^3$	200 $\mu g/m^3$	100$\mu g/m^3$	
RespirableParticulate Matter (RPM) (size less than 10 microns)	Annual Average*	120 $\mu g/m^3$	60 $\mu g/m^3$	50 $\mu g/m^3$	- Respirable particulate matter sampler
		150 $\mu g/m^3$	100 $\mu g/m^3$	75 $\mu g/m^3$	
Lead (Pb)	Annual Average*	1.0 $\mu g/m^3$	0.75 $\mu g/m^3$	0.50 $\mu g/m^3$	- ASS Method after sampling using EPM 2000 or equivalent Filter paper
	24 hours**	1.5 $\mu g/m^3$	1.00 $\mu g/m^3$	0.75 $\mu g/m^3$	
Ammonial	Annual Average*	0.1 mg/ m^3	0.1 mg/ m^3	0.1 mg/m^3	
	24 hours**	0.4 mg/ m^3	0.4 mg/m^3	0.4 mg/m^3	
Carbon Monoxide (CO)	8 hours**	5.0 mg/m^3	2.0 mg/m^3	1.0 mg/ m^3	- Non Dispersive Infra Red (NDIR)
	1 hour	10.0 mg/m^3	4.0 mg/m^3	2.0 mg/m^3	Spectroscopy
*	Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval				
**	24 hourly/8 hourly values should be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days.				

Source: Environment, Effluent, Emission and Noise Standards & Guidelines, KSPCB, Trivandrum, 1997

The Ambient Air Quality Status described in terms of Low (L), Moderate (M), High (H) and Critical (C) for Industrial (I), Residential and mixed use (R) areas of Cities/Towns in different States/Union Territories in India is given in table 3.4.

Table: 3. 4

Ambient Air Quality Status

	Annual Mean Concentration Range (µg/m³)			
Pollution Level	Industrial		Residential	
	SO_2 & NO_2	SPM	SO_2 & NO_2	SPM
Low (L)	0-40	0-180	0-30	0-70
Moderate (M)	40-80	180-360	30-60	70-140
High (H)	80-120	360-540	60-90	140-210
Critical (C)	>120	>540	>90	>210

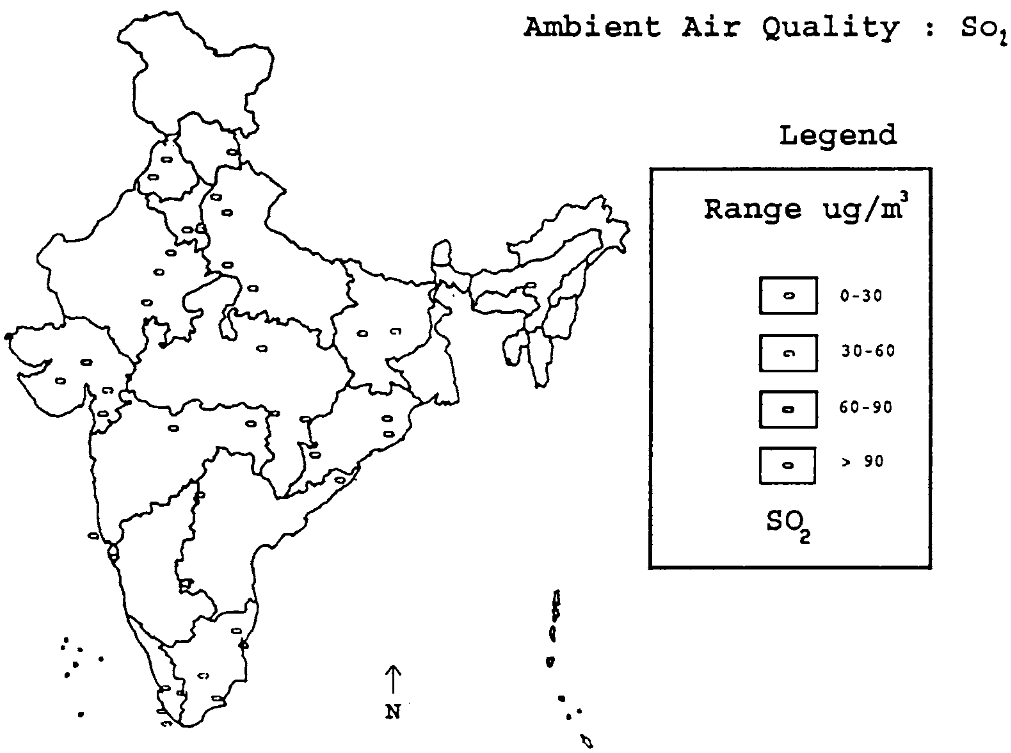
Source: Environment, Effluent, Emission and Noise Standards & Guidelines, KSPCB, Trivandrum, 1997

The data available in India shows that concentrations of pollutant are typically within the national ambient air quality standards with the exception of particles. A recent case study (http://www.teriin.org/camps/monitored) that monitored RSPM twice a week at 10 stations in Delhi over a 13-month period between July 2000 and July 2001 reported that the mean RSPM concentrations averaged 204 mg/m³, considerably above the US annual PM_{10} standard of 50 mg/m³. The correlations between NO2 and RSPM concentrations were extremely weak, suggesting that sources other than road traffic were contributing significantly to ambient RSPM (World Bank, 2002).

As mentioned earlier, air quality in India is measured in terms of three components- SO_2, NOX and SPM. These are depicted below. The, map 3.1 below shows the Ambient Air quality scenario of SO_2in India

Map: 3.1

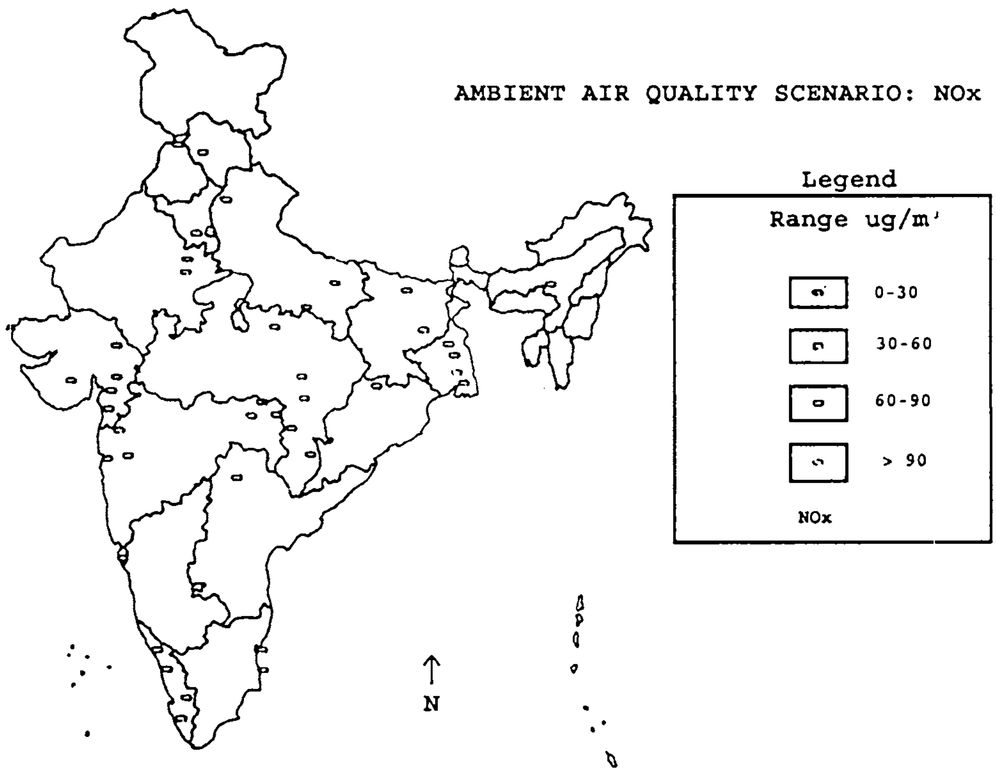
Ambient Air quality scenario of SO_2 in India



The, Map 3.2 below shows the Ambient Air quality scenario of NOX in India.

Map: 3.2

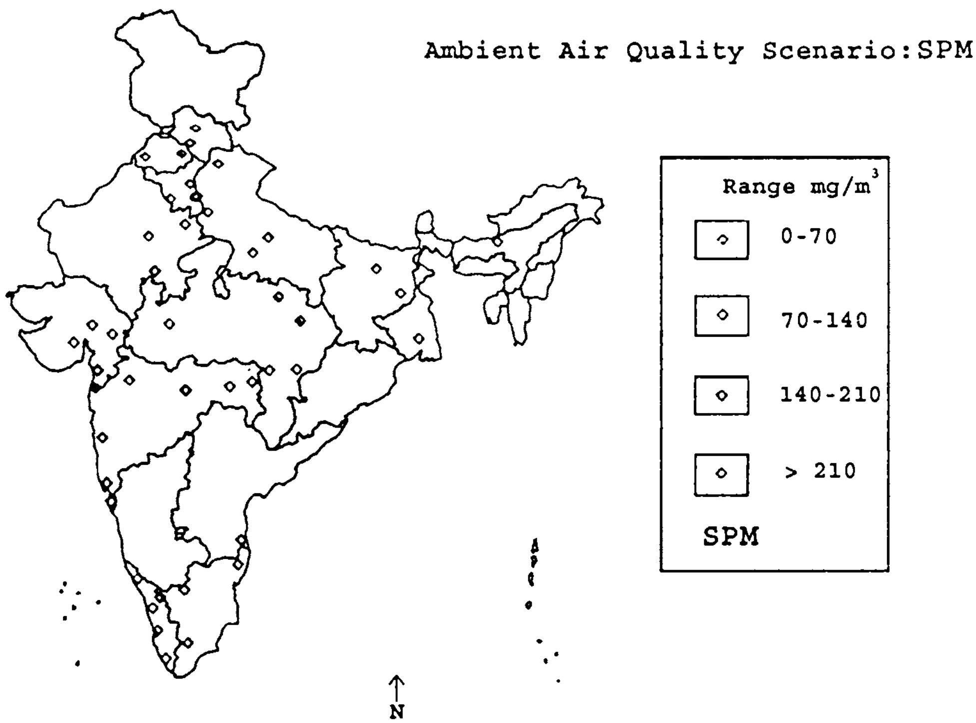
Ambient Air quality scenario of NOX in India



The, Map 3.3 below shows the Ambient Air quality scenario of SPM in India

Map 3.3

Ambient Air quality scenario of SPM in India



3.1.4 Air Pollution Management Policies in India

With a view to control various types of air pollution, the Government of India came forward with a set of legal and institutional measures. These initiatives are outlined in the National Conservation Strategy and Policy Statement on Environment and development; and policy statement for abatement of pollution (1992), which is given in the table 3.5:

Table: 3.5
Air Pollution Management Policy Statements of India

Pollution Management Policy	Pollution Management Measures
Technological Measures	▪ Use of Clean fuels and clean Technologies, Energy efficient devices, air pollution control systems ▪ Incentives for environmental benign substitutes, technological and energy conservations.
Zoning Strategy	▪ Setting up of source specific and area wise air quality standards and time bound plans to prevent and control pollution. ▪ Proper location of projects to minimize the adverse impact on people and environment ▪ Location of industries as per environmental guidelines for siting of industry ▪ Priority to compatible industries so that, wastes from one could be used as raw material from the other, thusminimizing net pollution. ▪ Development of green belts with pollution tolerant species
Fiscal Incentives & Economic Instruments	▪ Incentives for environmentally clean technologies, recycling and reuse of wastes and conservation of natural resources. ▪ Operationalization of 'polluter pays principle' by introducing emission tax, resource cess for industry and implementation of standards based on resource consumption and production capacity ▪ Public liability insurance against loss or injury to life or property Internalizing the environmental safe guards as an integral component of the total project cost
Command and Control	▪ Enforcement of pollution control norms in various types of industrial units depending on their production processes/technologies and pollution potential; particularly attention to be paid to highly polluting industries. ▪ Introduction of Environmental audit ▪ Environmental impact assessment from the planning stage and selection of sites for location of industries ▪ Clearance by MOEF of all projects above a certain size and in fragile areas.

Souice:Ministry of Environment and Forests, GOI. (1992).
Compiled from 'Clean AIR, *Environmental Governance-4', IGIDR, Mumbai*

3.2 Air Quality in Kerala

Kerala is generally perceived as the green belt of India. An average 'Keralian' was not concerned about the deterioration in air quality since these were not considered as serious issues of governance till recently (Rene Veron 2000). However, around 1980's environmental problems such as industrial or automobile pollution, deforestation, paddy conservation and deterioration of backwater ecosystems have been raised as major development issues by various NGOs such as Kerala Peoples Science Movement (Kerala Shastra Sahitya Parishat KSSP), Greenpeace and local people's organisations.[4]

Today industrial air pollution is causing real threat to the livelihood securities of Kerala's population in many ways. Comparing the magnitudes of major air pollution indicators of other States, Kerala is relatively less polluted (State Pollution control Board, 1999). However, recent statistics of the Central pollution Control Board show that Kerala ranks fourth in the case of closer of industrial units[5] due to pollution. Moreover, the Central Pollution Control Board (CPCB) and the Kerala State Pollution Control Board (KSPCB) have identified some heavily polluted spots in the state.

---

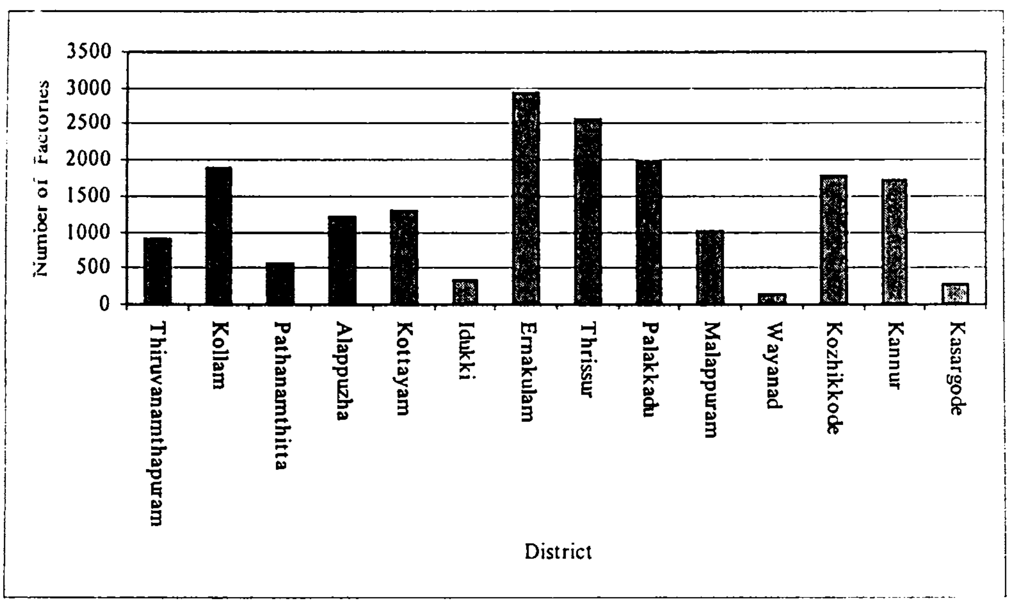
[4] During the last few years, these issues have been reflected in a number of environment-livelihood related agitations and protest movements in various parts of the State such as in Plachimada (Ground water), Eloor (Industrial Pollution), Karimugal (Industrial pollution), Karunagapally (Sand Mining) etc. Even though, no general environmental awareness has yet evolved on a large scale, people seem much more concerned about specific local environmental changes when it directly affects their livelihood.

[5] See figure 3.1.

Air pollution in the state is mainly due to Industrial and vehicular emissions. For the last few decades the state has been relentlessly taking efforts to boost up industrial growth (see map 3.4 of the State attached alongside). It has introduced a wide spectrum of policy initiatives as a result which various industrial clusters have emerged in different parts of the state. Currently, Kerala is the third best state in composite ranking in respect of industrial attractiveness among the Indian states (Economic Review, 2002). District wise distribution of registered working factories in Kerala is shown in figure 3.2 below:

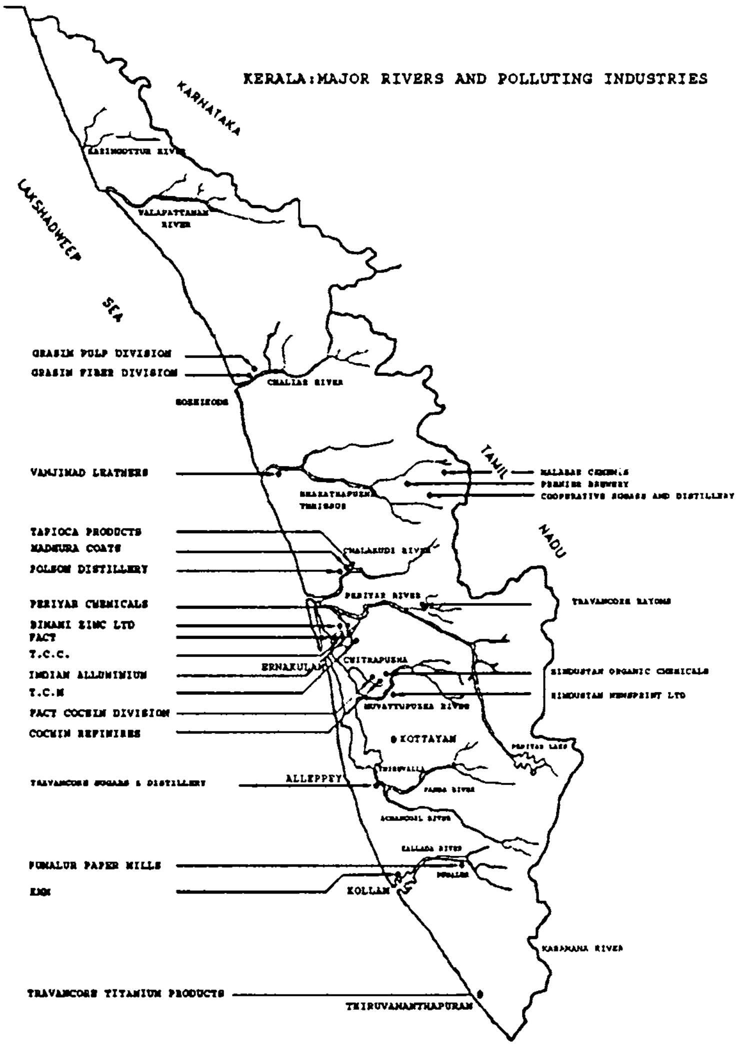
Figure 3.2

District wise distribution of registered working factories in Kerala 2001



Source: Economic Survey, Government of Kerala 2002

Map 3.4
Kerala: Major Polluting Industries

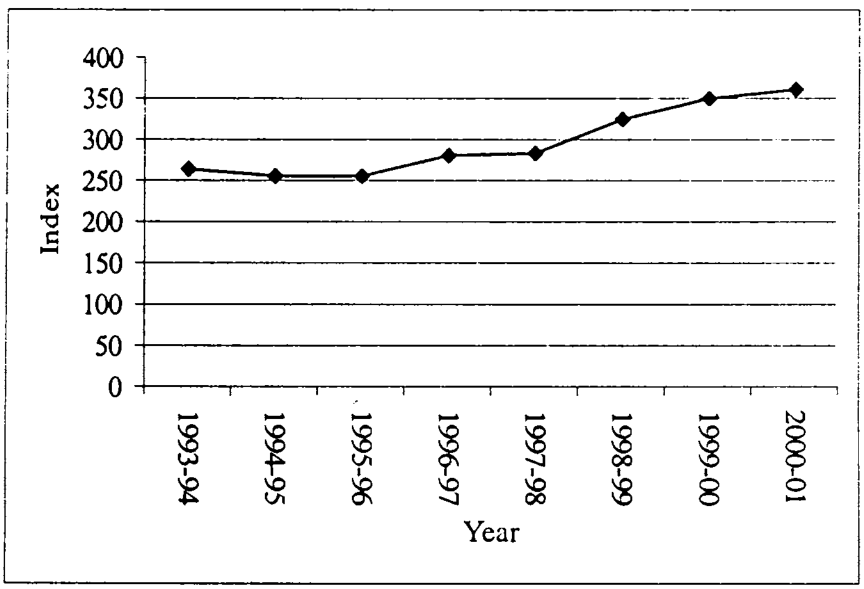


In the case of registered working factories, Ernakulam ranks first with 2944 industries. The lowest is Wayand with 143 industries. In 1990 the number of registered working factories in Ernakulam was 1931. By a decade the number is doubled.

For last ten years working industrial units and industrial production has increased in the state considerably. Index of industrial production for last decade is shown in the figure 3.3.

Figure 3.3

Index of Industrial production



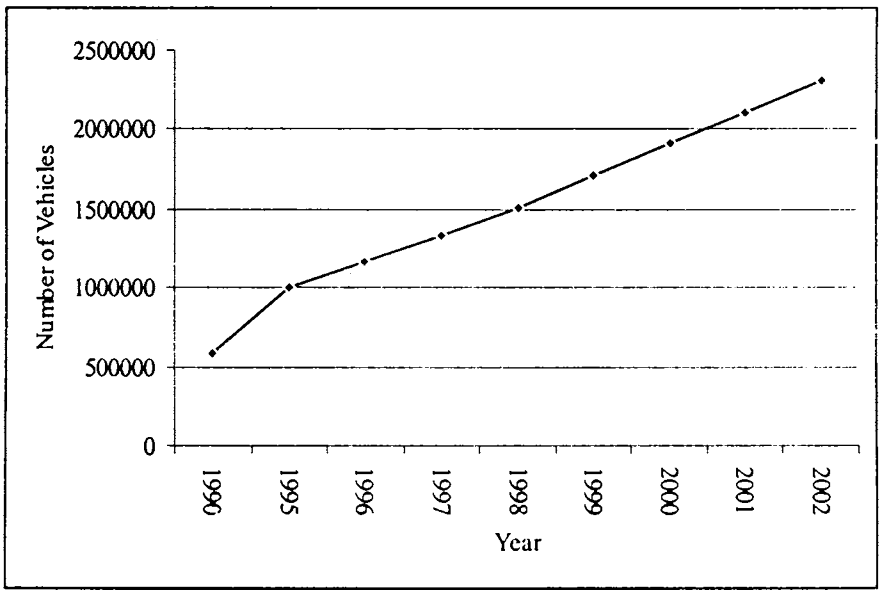
Source: Fconomic Review, Government of Kerala, 2002

The general index of industrial production registered a marginal increase from 351.24 in 2000-2001 to 360.20 in 2001-2002.

Besides the Industrial sector, the transport sector in urban areas has created major problems of air pollution due to the rapid growth in the number of motor vehicles. Number of registered vehicles has increased considerably in the state for last ten years. The vehicle density in the state is very high compared to many other states in India. Kerala has 5958 vehicles per 100 sq. km. of area and 7272 of vehicles per lakh population. Growth of motor vehicles in Kerala for last ten years is shown in figure 3.4.

Figure 3.4

Growth of motor vehicles in Kerala



Source: Economic Review, Government of Kerala, 2002

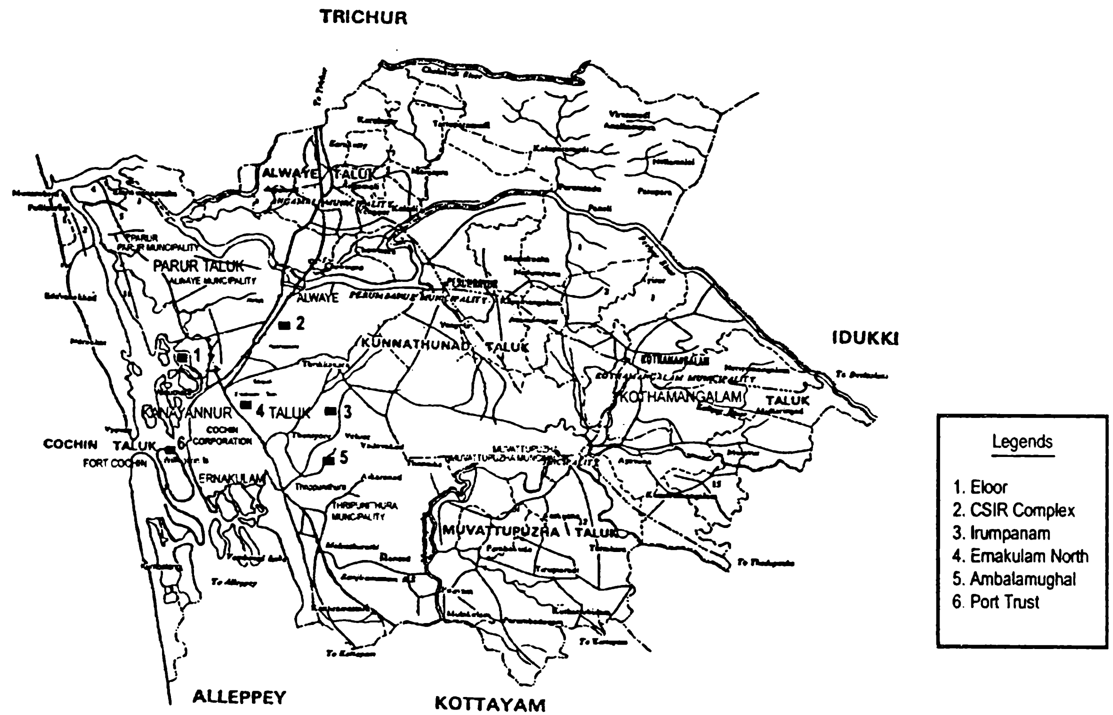
The number of vehicles is increasing at a rate of 10 percent annum, leading to concurrent increase in serious air pollution.

3.3 Air Pollution and Environmental Quality in Cochin Industrial Agglomeration

3.3.1 Location of Cochin industrial agglomeration

Cochin industrial agglomeration, lie within the administrative boundaries of Ernakulam district. It is ecologically rich with its terrestrial, wetland and river/backwater ecosystems. However, this environment began to face a serious crisis with the highest concentration of industries and vehicles which are the major causes of pollution in the State. Map of Ernakulam district, showing the study area is given in figure 3.5 below:

Map: 3.5
Map of Ernakulam District



The area of Ernakulam district, where the Cochin industrial agglomeration situates, accounts to 6.19 percent of the total area of the state with 2407 Km^2. In the case of population density, the district ranks third next to Alapuzha and Thiruvananthapuram. Even though significant developments have taken place in industrial and tertiary sectors, the district still have a large number of people engaged in agriculture and allied activities. Dense population, urbanization, land reforms, change in family systems, etc., have resulted in the fragmentation of land. Hence a shift in the economic activity from agriculture to other sectors is taking place. The district is divided into three natural divisions - High land, Middle land and Lowland. The study area Cochin Industrial agglomeration situates in low land space. The most important river in the study area is Periyar, longest river in the district, stretched over a length of 229 Kms. The river plays a prominent role in the development of agricultural, industrial and commercial sector of the district. The agglomeration is also blessed with an attractive network of canals and backwaters.

As explained in the introduction, in this study, Cochin Industrial agglomeration is defined to include the industrial area of Ernakulam district, comprising the Cochin Corporation, One Municipality, Kalamassery, and three panchayats, Vadavucode-Puthercruz, Thiruvankulam and Ellor (See map of Ernakulam District alongside) This area is the industrial centre of Kerala. A number of large, medium and small scale industries are clustered in and around Cochin. Most of the industries are located on the banks of the rivers 'Periyar' and 'Chitrappuzha'. Cochin tops in the case of number of registered working factories among all districts in the state. Demographic features of the agglomeration are given in table: 3.6 below

Table: 3.6

Demographic features of Cochin Industrial Agglomeration, 1991

Panchayath/ Muncipality/ Corporation	Area (Sqkms)	No. of Wards	No. of Households	Population- Male	Population- Female	Population- Total	Density /Sq. Km
Eloor (Eloor)	14.21	10	6038	15873	15997	31870	1739
Thiruvamkulam (Irumpanam)	10.49	9	3966	9188	9224	18412	1755
Vadavucode- Puthen Cruz (Ambalamugal)	36.89	11	5595	13440	12704	26144	709
Kalamassery (Kalamasery, CSIR Complex)	27		11430	27789	26553	54342	2013
Cochin Corporation (Port Trust, Emakulam North)	94.88		103751	283432	281157	564589	5951
Total	183.47	30	130780	349722	345635	695357	12167

Source: Panchayat Level Statistics, 2000, for Emakulam, Dept. of Economics and Statistics,

The workers and work participation of the agglomeration is given in the table 3.7 below

Table: 3.7

Workers and work Participation 1991

Panchayath/ Muncipality/ Corporation	Main Workers	Marginal Workers	Total
Eloor (Eloor)	8953	430	9383
Thiruvamkulam (Irumpanam)	5640	302	5942
Vadavucode- Puthen Cruz (Ambalamugal)	8216	745	8961
Kalamassery (Kalamasery, CSIR Complex)	16521	750	17271
Cochin Corporation (Port Trust, Ernakulam North)	169370	6716	176086
Total	208700	8943	217643

Source: Panchayat Level Statistics, 2000, for Ernakulam, Dept. of Economics and Statistics

3.3.2 Major Industries in Cochin Industrial Belt

Both large and small scale industries are located at Cochin industrial agglomeration. The line of production ranges from fertilizers, chemicals, leather tanneries, pesticides, wood industries, and minerals to Information Technology based industries. The major industries located in Cochin Industrial agglomeration with their products are given in table: 3.8

Table: 3.8
Leading Air Polluting Industries of Cochin Industrial Agglomeration

Sl No:	Name	Year of Establish ment	Products
1	Travancore Cochin Chemicals (TCC)	1951	Caustic soda lye,Caustic soda flakes Liquid Chlorine, HCL Sodium hypo chlorite
2	Binani Zink Edayar	1967	Electrolytic Zinc
3	Appollo Tyres Kalamassery	1972	Vehicle tyres
4	Hindustan Insecticides Ltd	1956	Endosalfan Monocrotophos Butachlor MalathionDicofol Carboxin Copper Oxychloride Mancozeb , DDT
5	BSES Kerala pOwer Ltd	2000	Electricity from Naphtha
6	Merchem Ltd, Industrial Development Area, Kalamassery		Thiuram and Dithiocarbamate Accelerators, Non-staining Antioxidants, Water Treatment Chemicals
7	Merchem Ltd, Industrial Development Area, Edayar, Cochin.		Thiuram and Dithiocarbamate Accelerators, Processing Aids, Pesticide Intermediaries
8	Merchen Ltd, Udyogamandal, Cochin		Thiazole and Sulphenamide Accelerators, Staining Antioxidants
9	FACT, Udyogamandal	1947	Caprolactam Ammonium Sulphate Ammonia
10	FACT, Cochin Division	1970	Fertilizers, sulphuric acid,phosphoric acid
11	Kochi refineries Ltd	1963	LPG, petrol, diesel, kerosene, naptha, benzene,toluene, LSHS, furnace oil, ATF, speciality solvents, bitumen, rubberised bitumen
12	Hindustan Organic Chemicals Ltd, Ambalamugal	1988	Phenol, Acetone & Hydrogen peroxide, propylene
13	Philips Carbon Black Ltd		Carbon Black
14	Indian Rare Earth		Zircon Ilmenite, Rultile, Rare Earth Chloride
15	Indian Aluminium Company, Limited (Indal),	1938	bauxite mining, alumina refining, power generation, aluminium smelting to semi-fabricated products of sheet, foil and extrusions aluminium scrap recycling
16	Periyar Chemicals		formic acid sodium sulphate
17	United catalysts India Ltd		catalysts for Fertiliser, Petrochemical and Sponge Iron industries

Source: Survey data,2001- 2002

The pollutants emitted from these industries and vehicles into the air and water bodies of Periyar, Chitrapuzha and Cochin Backwaters have created negative externalities to local surroundings and resulted in degradation of ecological biodiversity (Thomson,2002 and 2003). No proper action was taken by the concerned authorities to internalise these externalities and this in turn has lead to people's initiatives for environmental protection. Within the geographical sphere of the Cochin Industrial Agglomeration, a number of environment related protest movements have evolved in the past few years[6]. Health related studies in Cochin indicated that incidence of respiratory diseases is directly proportional to air pollution. Greenpeace in a study "Status of Human Health at Eloor Industrial Estate, Kerala"(2003), which clearly identified an alarming incidence of diseases like Cancer, Bronchitis, Congenital Malformations, Asthma, Allergic dermatitis and Stomach ulcers amongst the residents of the industrial belt of Cochin. The report said that, over 247 chemical industries in the Eloor industrial estate have been releasing toxic wastes into the air, land and water of Eloor which has damaged life beyond repair. The methodology adopted was to do a comparative study between the residents of Eloor and Pindimana, up stream the River Periyar and still

[6] Local community in the Cochin is facing serious pollution related problems. Pollution creates serious threats to the local community and natural environment. For instance, On 8th July 1998, an instance of mortality of fishes occurred in Chithrappuzha, Champakara Canal and adjacent waters of Cochin Estuarine system. Large number of fishes of different varieties and sizes are found floating dead on the water at Champakkara, Eroor and Irumpanam of Chithrappuzha river. The investigation report by Kerala State Pollution Control Board regarding the cause of massive destruction of aquatic fauna in the Chithrappuzha River and its estuarine regions stated that the incident resulted from the presence of a high concentration of free ammonia and ammonical nitrogen, which entered the water sources as an industrial effluent (Court report O.P No: 21970/98 H.C Kerala). People in Eloor and Ambalamugal have been protesting against the polluting industries in the regions for last few years in this regard.

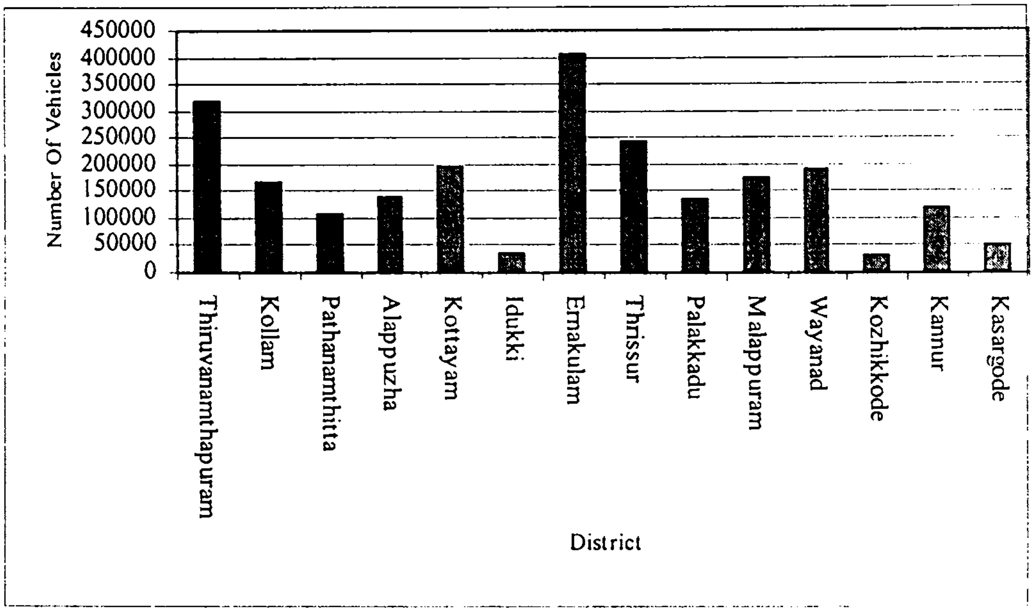
unpolluted at large. According to the report, the chances that Cancer may affect the people of Eloor are 2.85 times higher here than if they were to be living anywhere else. Again, residents of Eloor are exposed to a hig her risk of 3.4 and 2.2 respectively to be fatally affected by Bronchitis and Asthma.

Manufacturing sector contributes to environmental degradation through the use of inputs and the production of outputs. On the input side they caused depletion of natural resources, while in the output side, they generate pollutants that are harmful to both human being and natural environment.

Vehicular emissions are another key source of industrial pollution in Cochin. It is observed that nearly 557 vehicles are newly added to the vehicle population every day in the state (Economic Review 2002) and the highest vehicle population growth is recorded in Ernakulam district i.e. 405661 (17.52 prcentage) followed by Thiruvanamthapuram with 320061 (13.82 percentage). District wise comparison of number of motor vehicles is shown in figure: 3.5.

Figure: 3.5.

District wise number of motor vehicles as on 31.03.2002



Source: Economic Survey, 2002, Govt. of Kerala.

It is clear from the above facts that Cochin has the highest vehicular density in Kerala. Besides the number of vehicles on the road, poor road quality and poor maintenance of roads in urban have increased air pollution.

3.3.4 Air Quality Trends in Cochin

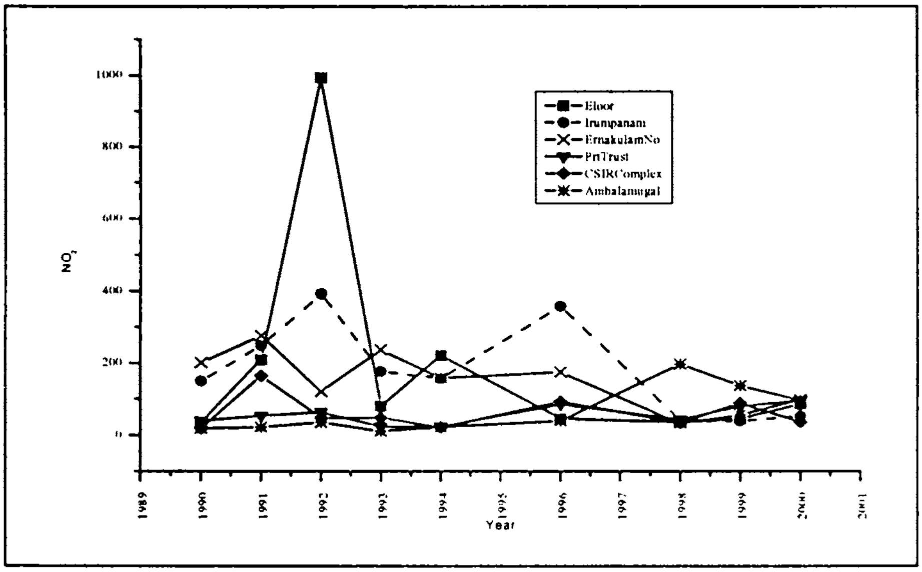
Air pollutants mainly consist of Oxides of Nitrogen (NOX), Sulphur Dioxide (SO_2) and Suspended Particulate Matter (SPM). The concentration of these in urban areas causes severe pollution to the surroundings. The largest proportion of urban air pollution arises from transportation and industries.

Oxides of Nitrogen (NOX)

The trend of NOX for six locations in Cochin, such as, Eloor, Irumpanam, Ernakulam North, Port Trust, CSIR Complex and Ambalamugal, are shown in figure 3.6

Figure 3.6

Trends on NOX at different locations of Cochin



Source: Ambient Air Quality Data: 1989-2000, CPCB

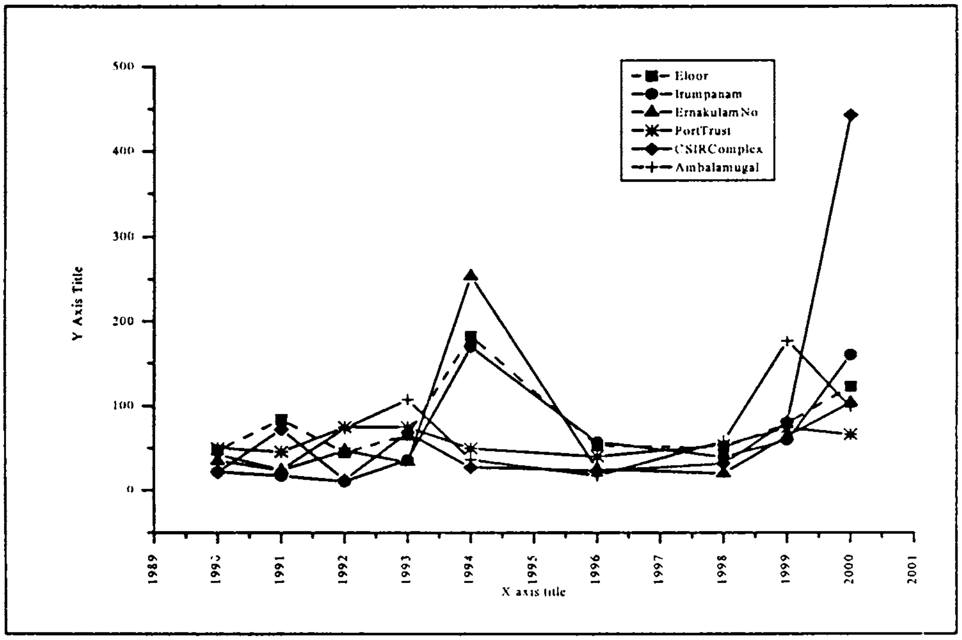
Annual average NOX trends for residential and industrial zones in Cochin are above the permissible levels for residential and industrial locations of Eloor, Ernakulam Noth and Irumapanam for last 12 years and in Ambalamugal for last six years. The maximum permissible limit in residential area is 90 $\mu g/m^3$ and 120 $\mu g/m^3$ in industrial area.

Sulphur Dioxide (SO_2)

The trend of SO_2 for six locations in Cochin, such as, Eloor, Irumpanam, Ernakulam north, Port Trust, CSIR Complex and Ambalamugal are shown in figure 3.7.

Figure 3.7

Trends on SO_2 at different locations of Cochin



Source: Ambient Air Quality Data: 1989-2000, CPCB

The maximum permissible limit of SO_2 in residential area is 90 $\mu g/m^3$ and 120 $\mu g/m^3$ is in industrial area. Annual average SO_2 trends for residential and industrial zones in Cochin shows a mixed trend, but are above the permissible levels in Eloor, Ernakulam Noth and Irumapanam between 1996-1997. As in the case of SO_2 in

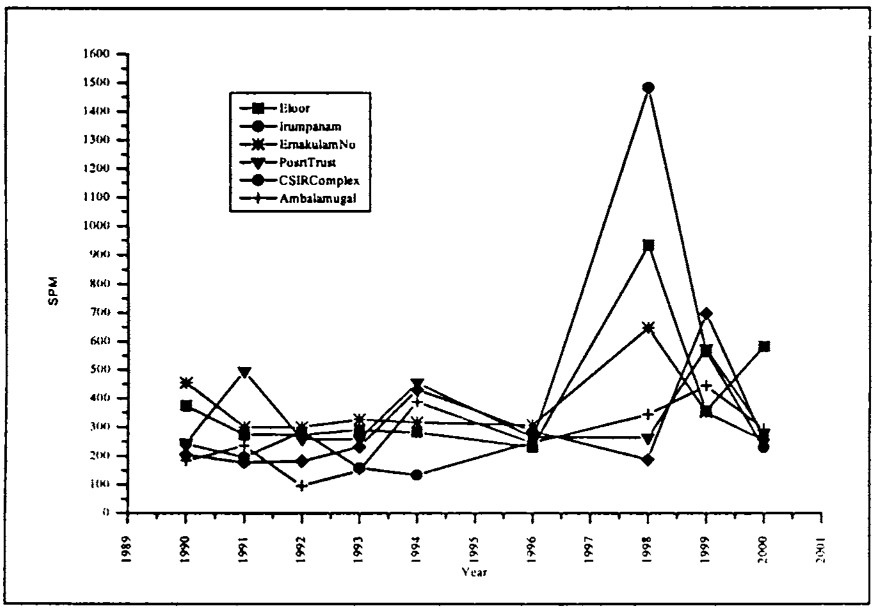
Ambalamugal it is high for the last four years. CSIR Complex has shown a remarkable increase in 2000.

Suspended Particulate Matter (SPM)

The trend of SPM for six locations in Cochin are shown in figure 3.8

Figure 3.8

Trends on SPM at different locations of Cochin

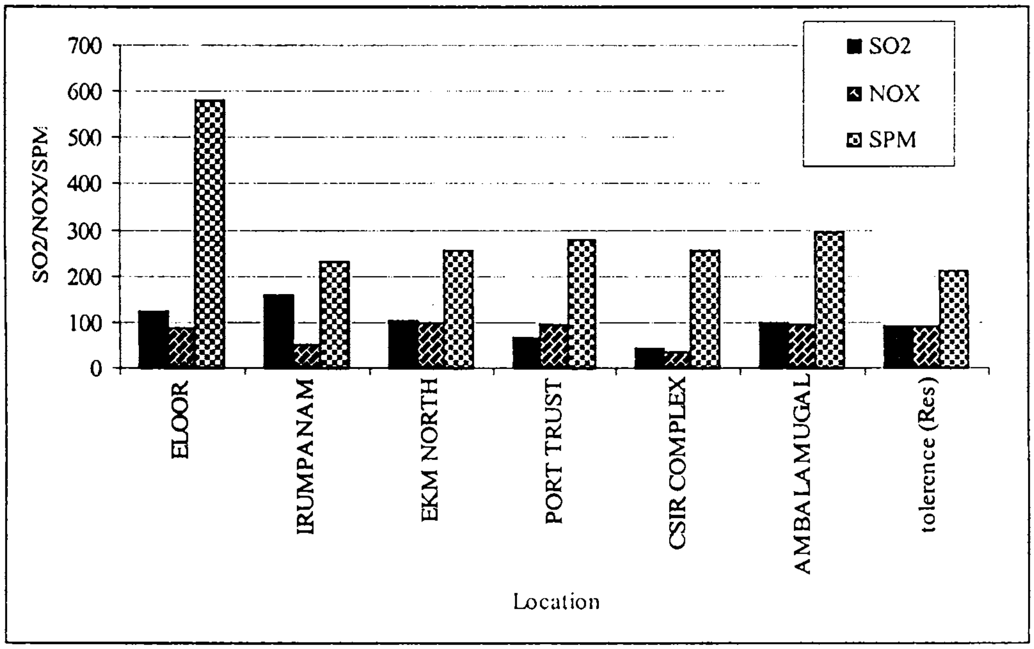


Source: Ambient Air Quality Data: 1989-2000, CPCB

The maximum permissible limit of SPM in residential area is 210 $\mu g/m^3$ and 540 $\mu g/m^3$ is in industrial area. Annual average SPM trend for Ernakulam North shows an extraordinary hike in 1991with a value of 14872 $\mu g/m^3$ to avoid the influence of such an extreme value, the SPM coefficient for 1991 is averaged to 300 and graph is plotted again. The plot is given in figure 3.8 and it shows the SPM values above the permissible levels in Eloor, Ernakulam Noth and Irumapanam, Port Trust and CSIR complex after 1996.

The Ambient Air Quality data for the year 2000 is regarded as the pollution variable in the cross sectional data. Values for NOX, SO_2, and SPM has exceeded residential tolerance level in many of the locations for the year. Ambient Air Quality Monitoring Data for the year 2000 with residential tolerance level for six monitoring stations are shown in figure 3.9.

Figure 3.9
Ambient Air Quality Monitoring Data for the year 2000



Source: Ambient Air Quality Monitoring data, CPCB, 2000.

SPM values are considerably higher than residential tolerance level in Eloor and Ambalamugal. SO_2 is higher in Irumpanam and Eloor. NOX is higher in Ambalamugal and Ernakulam North.

Pollutants, such as, Particulate matter, Nitrogen oxides and Sulphur dioxide generated by rising industrial activities, and vehicular transport result in deterioration air quality and wide spread of exposure of large population segment. It affects the health of human being, property of the surroundings. The above explained data, therefore may be used to estimate the benefit and cost function of air pollution damage.

3.4 Conclusion

Kerala is generally perceived as a less polluted state when compared to the rest of the country. However, it is observed from the above analysis that there are pockets of pollution in many parts of Kerala, especially in and around the Cochin industrial agglomeration. This chapter provided a detailed sketch of the air pollution scenario in the study area. We began with an overview of the air pollution scenario in India followed by a general description of industrial air pollution in Kerala and Cochin. The important sources of air pollution identified in Cochin are emissions from industries and automobiles. Comparatively, most of the studies conducted in Cochin are on water pollution. Local environmental organisations

NGOs and academicians have conducted studies on water pollution in Periyar River and Cochin Estuary. On the other hand, very little data is available to describe the status of air pollution in Cochin.

Air pollutants mainly consist of Oxides of Nitrogen (NOX), Sulphur Dioxide (SO_2) and Suspended Particulate Matter (SPM). From the available data presented above, it was observed that emission levels in many part of Cochin are above the prescribed levels, causing serious damage to health and property values. Hence, in the context of Kerala, environmental issues such as air pollution need to be seriously considered and its damage to human health and property values properly estimated. These issues are examine and studied in detail in the forthcoming chapters.

Chapter: 4

Impacts of Air Pollution on Human Health

In the previous chapter we described the nature and sources of air pollution in Cochin and indicated the possible consequences of an increase in the levels of air pollution to human health and urban property values. Constant exposure to polluted environment due to air pollution, most often, leads to morbidity[1] and sometimes mortality[2]. As a matter of fact, a million of the industrial workforce who participate directly in various production processes and post- production activities in these factories and the general public settled in and around the agglomeration is the direct victims of this social evil. Since the deterioration of air quality ruins their health and welfare, they try to avert the negative influences of air pollution. This aversive behaviour of individual households is to be seen as part of their attempts to regain

[1] Health effects of environmental pollution ranges form morbidity, such as hospital admissions, restricted activity days etc. to mortality effects (Murty and Kumar, 2002). Morbidity is defined by the U. S. Public Health Service as, 'a departure from a state of physical or mental well being, resulting from disease or injury, of which affected individual is aware (Peterson, 1975). It can be classified in a variety of ways based on the duration of condition, such, as chronic or acute, degree of impairment of activity or type of symptoms and could be measured by cases of different types of illness. The degree of impairment of activity is an important way of measuring morbidity. There are several categories of degrees of activity impairment, namely, Restricted Activity Days (RAD), Bed Disability Days (BDD), Work days Lost (WDL). Restricted Activity Days are those on which a person is able to undertake some, but not all, activities. Bed Disability Days are those in which a person is confined to bed, either at home or institution. Work days Lost are those on which a person is unable to engage in ordinary gainful employment. For convenience, the present study incorporates the three concepts under one head, RAD (U S Department of Health, 1964).

[2] ' 'Mortality, on the other hand, refers to a well defined event – death – which for ceremonial and legal reasons almost always is noted and made part of an official record' (Freeman, 1993).

the welfare losses due to air pollution. It is therefore significant and necessary that we value the welfare losses / benefits due to air pollution. The main focus of this chapter, hence,.is to estimate values of health effects due to air pollution in the Cochin industrial agglomeration. We adopt the Revealed Preference Approach and Contingent Valuation Methods to estimate monetary values of changes in human health associated with the reduction in environmental quality. This chapter is divided into 5 sections. In section 1 we present the health production function model which is used for estimating the household's willingness to pay for reduced morbidity. In section 2, we present a detailed description of how the environmental variables are related to different socio economic characteristics of sample households in the study area. Section 3 deals with the estimation of willingness to pay using Health production Function. In section 4, we estimate the willingness to pay using the Contingent Valuation Method. An attempt is made in section 5 to compare these willingness to pay estimates. The last section gives a summary of this chapter.

4.1 Valuation of Morbidity: The Health Production Function Model

The household health production function model is used to estimate the values that households place on reduced morbidity due to reduction in air pollution. The model adopted in this study although follows the general formulations proposed by Grossman (1972), Cropper (1981) and Iberini and Krupnick (2000), some of the independent variables like air conditioners, air purifiers etc. are not included in this model as these are either absent or used in a very restricted manner.

Accordingly, the health production function is specified as

$$S = s(C, M, H, K) \quad \text{-------------} \quad (1)$$

Where, S = Number of sick days
C = Environmental Quality
M = Mitigating Activities
K = Stock of social capital (such as education, sex....)
H = Stock of health Capital

The utility function of the individual household is defined as

$$U = u\,(Y, S, C, L, I) \quad \text{-------------} \quad (2)$$

Where,

Y = any private good, taken as numeraire
L = leisure
I = Income

Individual's budget constraint is written as,

$$I = I^* + Pw\,(T - L - S) = Y + Pm.M \quad \text{---------------} \quad (3)$$

Where,

Pw = wage rate

I^* = non labour income

T = total time available

Pm = price of mitigating activities

Individual maximizes Utility (2) subject to the budget constraint,

$$Max\ Z = u\ (Y, S, C, L, I) + \lambda\ (I^* + Pw\ (T - L - S) - Y - Pm.M)\ \text{---------------}\ (4)$$

First order condition for maximization is given as,

$$Uy = \lambda\ \text{---------}\quad (4.1)\ \text{where}\ Uy = \frac{\partial U}{\partial Y}$$

$$U_L = \lambda\ Pw\text{------}\quad (4.2)\ \text{where}\ Uy = \frac{\partial U}{\partial C}$$

$$U_S . S_M = \lambda P_W S_M + \lambda P_M\ ,$$

$$\frac{\lambda P_M}{S_M} = U_S - \lambda P_W\quad \text{--------------}\ (4.3),$$

from (4.3), we can write,

$$\lambda P_M = U_S . S_M - \lambda P_W . S_M\quad \text{--------------}\ (5)$$

the indirect Utility function is given as,

$$V = v(c, P_M, H, K, I) \qquad \text{--------------} \ (6)$$

by taking total differential of this function and equating to Zero, one gets,

$$dV = Vc.dc + Vp_M.dP_M + V_I.dI = 0$$

Assuming P_M is optimum $\partial P_M = 0$;

$$\frac{dI}{dC} = -\frac{V_C}{V_I} = -\frac{V_C}{\lambda} \qquad \text{--------------} \ (7)$$

considering the lagrangian function for maximization as indirect utility function and differentiate w.r.t I we get, $V_I = \frac{\partial V}{\partial I} = \left(\frac{\partial Z}{\partial I}\right) = \lambda$

similarly, Z (eqn.4) as V and differentiate w.r.t 'c' we get

$$= U_C + S_C(U_S - \lambda P_W) \qquad \text{--------------} \ (8)$$

substituting (5) in (8) we get

$$\frac{\partial I}{\partial C} = \frac{U_C}{\lambda} + \frac{S_C}{\lambda}\left(\frac{\lambda P_M}{S_M}\right)$$

$$\frac{\partial I}{\partial C} = -\frac{V_C}{\lambda} = -\left(\frac{U_C}{\lambda} + \frac{P_M S_C}{S_M}\right) \qquad \text{-------------} \ (9)$$

Equation (9) gives the MWTP for individual for improved environmental quality.

Since we don't get optimum value of M from the survey, in practical purpose we can't use the above expression for MWTP. So we have to estimate demand function for M as,

$$M = M\ (W, P_M, C, I, H, K) \quad \text{----------------} \quad (10)$$

These equations give optimum quantities of M.

Now take the total derivative of health production function,

$$\frac{dS}{dC} = \frac{\partial S}{\partial M} . \frac{\partial M}{\partial C} + \frac{\partial S}{\partial C} \quad \text{----------------} \quad (11)$$

This can be re written as

$$\frac{\partial S}{\partial C} = \frac{dS}{dc} - \frac{\partial S}{\partial M} . \frac{\partial M}{\partial C} \quad \text{----------------} \quad (12)$$

Multiply equation (9) with the first order condition given in (5)

$$\frac{-P_M}{\partial S / \partial M} = P_W - \frac{\partial U / \partial S}{\lambda} \quad \text{----------------} \quad (13)$$

this is done to get $\frac{\partial I}{\partial C}$ i.e. MWTP. $\frac{\partial I}{\partial C}$ in equation number (9) can be approximated to

$$\frac{\partial I}{\partial C} = -P_M . \frac{\partial S / \partial C}{\partial S / \partial M} = -P_M \left(\frac{S_C}{S_M} \right) \quad \text{----------------} \quad (14)$$

Since *Uc*–direct utility gains that can not be captured by Houschold Production function, i.e,

$$-P_M.\frac{\partial S/\partial C}{\partial S/\partial M}=\frac{\partial S}{\partial C}\left(P_W-\frac{\partial U/\partial S}{\lambda}\right)-\frac{\partial S}{\partial M}.\frac{\partial M}{\partial C}\left(P_W-\frac{\partial U/\partial S}{\lambda}\right)\text{------- (15)}$$

Substituting from (13) and rearranging, we will get, the marginal willingness to pay (MWTP) as

$$MWTP,\quad \frac{\partial I}{\partial C}=P_W\frac{\partial S}{\partial C}+P_M\frac{\partial M}{\partial C}-\frac{\partial U/\partial S}{\lambda}.\frac{\partial S}{\partial C}\qquad\text{--------------- (16)}$$

This expression shows that marginal willingness to pay (MWTP) for health benefits from reduced levels in pollution is the sum of observable reductions in the cost of illness, cost of mitigating activities and the monetary equivalent of disutility of illness due to air pollution (Freeman 1993)

4.2 Environmental and Socio-Economic Characteristics

To estimate WTP using the health production function, we collected the following categories of cross-sectional data from600 households[3] .

[3] See chapter1, section 1.5.2 for details

1. Ambient pollution levels to which the individual is exposed

2. Frequency, duration and intensity of symptoms (epidemiological data) experienced by households due to air pollution

3. Actions and costs that individual households incur to avoid or mitigate effects of air pollution

4. Other variables affecting health.

These sets of data are explained in the following sections.

4.2.1 Spatial Distribution of Major Air Pollutants in the Study Area

In order to analyze the economic impacts of air pollution on human health in Cochin industrial agglomeration, air quality has taken as the environmental variable in the health production function. In this method, we assume that individuals are aware of air quality levels and how these affect them. Air quality, in turn is composed of three factors – Sulphur Dioxide, Oxides of Nitrogen and Suspended Particulate Matter. These data were compiled from the Ambient Air Quality Monitoring Data set of Central Pollution Control Board. The ambient air quality status for all the six monitoring stations in Cochin is given in table 4.1.

Table 4.1

Ambient Air Quality for different locations: 2000 (in $\mu g/m^3$)

Location	SO_2	NOX	SPM
ELOOR	122.6	85.6	582
IRUMPANAM	159.6	52.4	229
EKM NORTH	103.6	98.3	254
PORT TRUST	66	96	280
CSIR COMPLEX	44.2	36.2	256
AMBALAMUGAL	98.2	95.5	295
Tolerance level (Residential)	60 - 90	60 - 90	140 - 210
Tolerance level (Industrial)	80 - 120	80 - 120	360 - 540

Source: CPCB, AAQM data, 2000

This table reveals that the SO2 concentration exceeds the maximum tolerance level for residential areas in Eloor, Irumpanam, Ernakulam North and Ambalamugal. It exceeded the maximum tolerance level for industrial areas in Eloor and Irumpanam only. In the case of Oxides of Nitrogen, the tolerance level for residential area exceeded in Ernakulam North, Port trust and Ambalamugal. It is interesting to note that concentrates of suspended particulate matter exceeded the tolerance level for residential areas in all stations. The industrial tolerance level exceeded the normal maximum values only at Eloor.

4.2.2 Epidemiological Data

Epidemiological data corresponds to measures on 'morbidity'. Morbidity could be measured by recording cases of different types of illness, or episodes. This data, collected during our survey is presented in table 4.2 below.

Table: 4.2

Epidemiological Status

Disease	Yes	%	No	%
Asthma	247	41.2	353	58.8
Puldiseas	136	22.7	464	77.3
Cardiac	66	11	534	89
Skin	139	23.2	461	76.8
Recfever	174	29	426	71
Eyeirr	199	33.2	401	66.8
Bronchitis	117	19.5	483	80.5
Cancer	12	2.0	588	98
Cough	299	49.8	301	50.2
Headache	362	60.3	238	39.7

Source: survey data,2001-02

The table reveals a very high incidence of headache, cough, asthma eye irritation and recurrent fever in the study area. Around 60 percent of the people are affected by head ache and 41 percent are affected by asthma.

4.2.3 Demand for mitigation

The health production function approach maintains that willingness to pay depends on variables that affect mitigating/ avoidance activities such as 'doctor visits', medication and use of alternate medicines. These data are presented below.

(a) Doctor visits

Defensive activities to avoid exposure to air pollution include both averting and mitigating activities. For estimating the demand for mitigating activities, doctor visit is taken as the independent variable. Theoretically, there exists a positive relation between level of pollution and doctor visits. Range and frequency of doctor visits for the last six months at the time of survey is tabulated in table 4.3 below.

Table: 4.3

Doctor visits for six months

No. of doctor visit	Frequency	Percent
0-10	350	58.3
10-20	207	34.5
20-30	41	6.8
30-40	1	0.2
>50	1	0.2
Total	600	100

Source: survey data 2001-02

It is clear from the table that around 60 percent of the people in the study are had visited doctors other than maternity, accidents or injury for last six months.

(b) The Number and Costs of Mitigation

Mitigating activities are actions that people undertake to mitigate exposure to air pollution, such as, doctor visits, medication etc. Table 4.4 below shows the percentage of mitigating activities undertaken in the study area:

Table: 4.4

Distribution of mitigating activities

Mitigating activity	YES	%	NO	%
Medication	572	95.3	28	4.7
Doctor visit	594	99	6	1
Folk medicine / others	491	81.8	109	18.2

Source: survey data 2001-02

The table clearly reveals that a substantial proportion of the sample respondents undertake mitigate\ing activities. For instance, 99 percent of the people visit doctors for medical related purposes. 95.3 percent takes medication. However among the doctor visit category, 58.3 percent visit a doctor within six months less than ten times. (Refer table: 4.3).

The costs of mitigation incurred by the sample respondents are tabulated in table 4.10 below:

Table: 4.5

Mitigating costs of respondents for six months

Amount (in Rs.)	Frequency	Percent
Below 1000	211	35.2
1000-2000	189	31.5
2000-3000	121	20.2
3000-4000	67	11.2
4000-5000	8	1.3
6000-7000	3	0.5
Above 7000	1	0.2
Total	600	100.0

Source: survey data 2001-02

The above table indicates that 87 percent of households spend below Rs. 3000 for mitigating activities for six months, from a period of 2001 June to January 2002. A very negligible number of house holds, that is, 2 percent, had spend an amount above Rs. 4000 for the period.

(c) Restrictive Activity Days (RAD)

For the purpose of estimation, Restrictive Activity Days, (RAD), for the last six months prior to the primary survey (2001 June to January 2002) was collected. As in the case of doctor visits, RAD also has a positive relationship with level of pollution. Number of Restrictive Activity Days (RAD) for the last six months is given table 4.6 below:

Table: 4.6

Restrictive Activity Days (RAD) for last six months

No. of RAD	Frequency	Percent
below 10	199	33.2
10 – 20	153	25.5
20 - 30	143	23.8
30 - 40	81	13.5
40 - 50	16	2.7
above 50	8	1.3
Total	600	100

Source: survey data 2001-02

This table shows that activities of about 33 percent of households impaired their activities for below ten days due to air pollution in Cochin industrial agglomeration during 2001 June to January 2002. Around 82 percent of the households were restricted from their activities below 30 days for the period.

(c) Averting Activities

Averting activities are the actions that people follow to avoid exposure to air pollution, such as, installing air filters, air conditioner or/and change in daily activities. Frequencies of averting activities in the present study are given in table 4.7:

Table: 4.7

Percentage of averting activities

Averting activity	YES	%	NO	%
Air purifier	10	1.7	590	98.3
Staying inside home	559	93.17	41	6.83
A/C	3	0.50	597	99.50

Source: survey data 2001-02

Since the major averting costs for installing air purifier and air conditioner are negligible (only 2.16 percentage), and are attributed to reasons other than air pollution, averting costs are not considered in the estimation.

4.2.4 Socio Economic Variables and the Data Set.

(a)Distribution of Age composition

Age is an important variable that determines the household's Willingness to Pay (WTP) to avoid illness. The age composition of the sample is given in table 4.8

Table: 4.8

Distribution of Respondents by Age

Age	Frequency	Percent
25 - 35	113	18.8
35 - 45	257	42.8
45 - 55	132	22.0
55 – 65*	80	13.3
above 65*	18	3.0
Total	600	100.0

Source: survey data 2001-02

*as income a major factor affecting WTP the survey was often concentrated on working household heads.

(b) Education

Education is another major indicator that determines the willingness to pay frequency of education of the sample is given in table 4.9:

Table: 4.9

Distribution of Levels of Education

Education level	**Frequency**	**Percent**
Post graduation	34	5.7
Graduate /professional	189	31.5
Higher secondary	321	53.5
High school	56	9.3
Total	600	100.0

Source: survey data 2001-02

According the data set collected on education, a major category of respondents came under higher secondary class, whish includes, pre-degree, plus two, ITI and other diploma courses.

(c) **Monthly Income**

Another key variable that determines the willingness to pay of an individual household is wage rate and monthly income. Monthly income for the sample households is given in table 4.10 below:

Table: 4.10

Distribution of Monthly Income

Amount (in Rs.)	Frequency	Percent
0 - 5000	119	19.8
5000 - 10000	277	46.2
10000 - 15000	197	32.8
15000 - 20000	7	1.2
Total	600	100.0

Source: survey data 2001-02

The table above reveals that around half of the households (46 percent) had a monthly income between Rs. 5000 and Rs. 6000. Around 99 percent of the households had a monthly income below Rs. 15,000.

The data set presented above could be used to estimate willingness to pay for avoiding sick days due to air pollution using health production function approach. Such an attempt in made in the following section.

4.3 Estimation of Marginal Willingness to Pay Using Health Production Function

A number of studies have used regression analysis to estimate the effects of pollution on morbidity[4]. Estimation of willingness to pay using household health production function is attempted in three steps. As the first step, we regressed 'number of doctor visits' on pollution dummies and other socio economic variables

[4] see section 2.1 in chapter 2 for a detailed review of these studies

of the respondents to see how pollution could influence a person's doctor visits. This represents the demand for mitigating activities. In the second step health production function is estimated considering restrictive activity days (RAD) as the dependent variable using two stage least square (TSLS) regression. The estimated coefficients are in turn used in the third step to estimate MWTP.

In fitting regression, the dummy in each variable case is as given below. For pollution, the six monitoring stations are divided in to three, based on the intensity of joint occurrence of pollution parameters, PM_{10}, SO_2 and NO_X – low pollution area, moderate pollution area and high pollution area. Low pollution areas are taken as the base category with value zero in all cases and moderate pollution area by value pdummy1 and high pollution area by pdummy2. In the case of education also, the total 600 respondents are divided into four classes, below SSLC, completed SSLC/PDC, graduate/Engineering and PG/professional. Below SSLC is taken as the base category. edummy1 indicates SSLC / PDC, edummy2 for graduate/engineering and edummy3 for pg/professional. In case of disease, 0 indicates 'No' and 1 'Yes'.

4.3.1 Demand for mitigating activities

Ordinary Least Square Regression is used to estimate the coefficient of doctor visits with respect to pollution. The regression equation is specified as follows:

$$docvisit = \alpha_0 + \alpha_1 \text{MONTHLY INCOME} + \alpha_2 \text{MTGCOST} + \alpha_3 \text{PDUMMY1} + \alpha_4 \text{PDUMMY2} + \alpha_5 \text{ASTHMA} + \alpha_6 \text{BRONCHITIS} + \alpha_7 \text{EYE IRRITATION} + \alpha_8 \text{RECFEVER} + \alpha_9 \text{EDDUMMY1} + \alpha_{10} \text{EDDUMMY2} + \alpha_{11} \text{EDDUMMY3} + \alpha_{112} \text{INSURANCE} + \varepsilon$$

Where,

α_0 = constant,

docvist = Doctor visit.

MTGCOST = Mitigating cost

PDUMMY1 = Pollution dummy for moderate polluted areas

PDUMMY2 = Pollution dummy for highly polluted areas

RECFEVER = Recurrent fever

EDUMMY1 = Education dummy for SSLC / PDC

EDUMMY2 = Education dummy for graduate/engineering

EDUMMY3 = Education dummy for post graduate/professional.

This equation represents the respondent's demand for mitigating activities. As explained in the model specified above, the demand for mitigating activities of an individual is a function of pollution, income, social capital like education plus variables measuring the individual's health stock. The regression results for the entire sample are presented in table 4.11 below.

Table: 4.11

Regression coefficients for Demand for Mitigating Activities

Dependent Variable: DOCVISIT				
Method: Least Squares				
Sample: 600				
Included observations: 600				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.256191	1.593062	2.671705	0.0078
MONTHLY INCOME	0.000226	6.48E-05	3.490030	0.0005
MTGCOST	0.000630	0.000205	3.068602	0.0023
PDUMMY1	2.761518	0.586475	4.708675	0.0000
PDUMMY2	7.436292	0.718365	10.35169	0.0000
ASTHMA	-0.117097	0.476454	-0.245767	0.8059
BRONCHITIS	3.426859	0.587683	5.831134	0.0000
EYE_IRRITATION	-0.461387	0.511448	-0.902119	0.3674
RECFEVER	2.032741	0.501705	4.051665	0.0001
EDDUMMY1	-1.957284	0.774376	-2.527564	0.0117
EDDUMMY2	-2.218922	0.838463	-2.646415	0.0084
EDDUMMY3	-4.854353	1.183087	-4.103124	0.0000
SMOKING	0.339311	0.487953	0.695377	0.4871
INSURANCE	0.025061	0.443977	0.056446	0.9550
AGE	0.013991	0.021799	0.641840	0.5212
R-squared	0.438607	Mean dependent var		10.77333
Adjusted R-squared	0.425172	S.D. dependent var		6.941825
S.E. of regression	5.263110	Akaike info criterion		6.184004
Sum squared resid	16204.69	Schwarz criterion		6.293927
Log likelihood	-1840.201	F-statistic		32.64654
Durbin-Watson stat	1.557627	Prob(F-statistic)		0.000000

Source: Regression results

The regression results reveal that pollution coefficients [α_3=2.76and α_4 =7.43] are positive and significant showing that the demand for mitigating activities is positively determined by pollution concentrates.

The following results are worth mentioning

- In moderate pollution areas (Irumpanam and Ernakulam North), the doctor visits are higher by 2.76 units than the low polluted area (CSIR and Post trust), where as in the highly polluted area (Eloor andAmbalamugal) it is higher by 7.43 units.

- Variables of mitigating cost and monthly income are significant at 1% level, but the influence of these variables on the number of doctor visits is very meager.

- Among the diseases, bronchitis is highly and positively significant. However, eye irritation and asthma are not significant.

- Education, a major indicator of social capital is significant in all cases. It is interesting to note that in all three cases, demand for mitigating activities is negatively related. The coefficients for SSLC, graduation and post graduation are 1.95, 2.21 and 4.85 respectively. This means that educated people undertake mitigating and averting activities other than doctor visit, because they are more aware about the reason and occurrence of diseases. All other variables, such as, smoking, insurance and age are found not significant.

4.3.2 Estimation of Health Production Function

To estimate health production function, 'restrictive activity days' (RAD) is used as the dependent variable. RAD was then hypothesized to be a function of various socio-economic variables, such as, monthly income, doctor visits, pollution dummies, occurrence of diseases dummies, education, smoking, insurance and age. Two Stage Least Square (TSLS) was selected as the appropriate regression method to estimate mitigating activity and health production function simultaneously. The data were checked for identification problem. The following regression equation is used to estimate health production function:

$$\begin{aligned} RAD = {} & \beta_0 + \beta_1 \text{MONTHLY INCOME01} + \beta_2 \text{MTGCOST} + \beta_3 \text{PDUMMY1} + \beta_4 \text{PDUMMY2} + \\ & \beta_5 \text{ASTHMA} + \beta_6 \text{BRONCHITIS} + \beta_7 \text{EYE IRRITATION} + \beta_8 \text{RECFEVER} + \\ & \beta_9 \text{EDDUMMY1} + \beta_{10} \text{EDDUMMY2} + \beta_{11} \text{EDDUMMY3} + \beta_{12} \text{INSURANCE} + \varepsilon \end{aligned}$$

Where,

β_0 = constant,
RAD = Restricted activity days
MTGCOST = Mitigating cost
PDUMMY1 = Pollution dummy for moderate polluted areas
PDUMMY2 = Pollution dummy for highly polluted areas
RECFEVER = Recurrent fever
EDUMMY1 = Education dummy for SSLC / PDC
EDUMMY2 = Education dummy for graduate/engineering
EDUMMY3 = Education dummy for post graduate/professional.

The results from the TSLS regression are reported in table 4.12

Table: 4.12

Estimation of health production function in Cochin Industrial agglomeration

Dependent Variable: RAD				
Method: Two-Stage Least Squares				
Sample: 600				
Included observations: 600				
Instrument list: DOCVISIT C MONTH_INCOME01 MTGCOST PDUMMY1 PDUMMY2 ASTHMA BRONCHITIS EYE_IRRITATION 01 RECFEVER EDDUMMY1 EDDUMMY2 EDDUMMY3 SOMKING INSURANCE AGE				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.359812	2.719414	1.603218	0.1094
MONTHLY INCOME	0.000189	0.000109	1.730367	0.0841
DOCVISIT	0.235822	0.069660	3.385345	0.0008
PDUMMY1	11.87259	1.004159	11.82342	0.0000
PDUMMY2	17.75279	1.278687	13.88361	0.0000
ASTHMA	0.293934	0.808914	0.363368	0.7165
BRONCHITIS	1.842179	1.012895	1.818727	0.0695
EYE IRRITATION	-0.864014	0.867066	-0.996481	0.3194
RECFEVER	2.426465	0.863909	2.808705	0.0051
EDDUMMY1	-1.866929	1.321697	-1.412524	0.1583
EDDUMMY2	-4.199711	1.432279	-2.932189	0.0035
EDDUMMY3	-5.897743	2.036497	-2.896024	0.0039
SMOKING	1.891167	0.827494	2.285414	0.0226
INSURANCE	1.334894	0.751577	1.776123	0.0762
AGE	-0.009845	0.036955	-0.266408	0.7900
R-squared	0.542899	Mean dependent var		20.70000
Adjusted R-squared	0.531960	S.D. dependent var		13.06552
S.E. of regression	8.938576	Sum squared resid		46740.41
F-statistic	49.62889	Durbin-Watson stat		1.651992
Prob(F-statistic)	0.000000			

Source: Regression results

The major inferences of this relationship are the following:

- The coefficients of pollution dummy in TSLS estimates remain positive and highly significant.

- In moderate pollution areas, restrictive activity days (RAD) are higher by nearly 12 percent compared to less polluted area, where as in highly polluted area, restrictive activity days are higher by 18 percent.

- Coefficient of income variable is significant at 8 percent; however income has less influence on restrictive activity days.

- Co efficient of mitigating demand is significant at 1 percent and positively related to RAD.

- Significance of disease dummy also follow the same pattern of mitigating demand. Bronchitis (1.84) and recurrent fever (2.42) are significantly related to number of RAD. Among these, coefficient of recurrent fever is higher, indicating that recurrent fever causes more RAD. In case of education, dummy for SSLC class is significant only at 15 percent level. Other two classes are significant at 1 percent level. All three are negatively related to RAD, as in the case of demand for mitigating activity.

- Co-efficient of smoking and insurance are significant at 2 and 7 percent levels respectively, indicating that RAD are higher for smoking people and insurance holders. Asthma, eye irritation and age are not significant.

4.3.3 Estimating Willingness to Pay

As explained in section 4.1 above, the individual household's willingness to pay for health benefits due to the reduction in the levels of pollution is the sum of value of lost working time, observed changes in mitigating activities and the monetary equivalent of disutility of illness due to air pollution and is estimated using the following equation.

$$WTP, \quad \frac{\partial I}{\partial C} = P_W \frac{\partial S}{\partial C} + P_M \frac{\partial M}{\partial C} - \frac{\partial U / \partial S}{\lambda} . \frac{\partial S}{\partial C}$$

where, λ the marginal utility of income, converts the disutility of illness into monetary terms and $\frac{\partial M}{\partial C}$ gives the optimal adjustments of M (demand for mitigating activities) to a change in pollution. The first two terms in the equation can be approximated by using the observed changes in illness and mitigating expenditures as the last term, representing the effects of disutility of illness could not be estimated[5].

Descriptive statistics for area wise estimate of willingness to pay is given in the table 4.13 below:

Table: 4.13

Willingness to Pay of Sample Households of Cochin Industrial Agglomeration by Stations

	No of households	Minimum	Maximum	Mean	Median	Mode	Std. Deviation
ELOOR	100	1356.25	8083.77	4413.71	4487.77	2712.49	1711.65
Irumpanam	100	735.37	6557.54	2997.08	2409.03	4170.74	1372.74
CSIR	100	00	00	00	00	00	00
Port trust	100	00	00	00	00	00	00
Ambalamugal	100	1391.36	9929.29	6273.70	6337.41	7204.39	1985.44
EKM North	100	893.51	6572.88	3617.29	3580.18	5381.02	1469.28
WTP Whole Sample	600	.00	9929.29	2883.63	2675.35	00	2642.32

Source: survey data 2001-02

The table reveals the following:

- The mean willingness to pay for the highly polluted areas (Eloor and Ambalamugal) of the Cochin industrial agglomeration, for the six months

5 As a practical matter by avoiding monetary equivalent of disutility of illness $\left(\frac{\partial U/\partial S}{\lambda}\cdot\frac{\partial S}{\partial C}\right)$, the observed lower bound of WTP is referred to as, *Private Cost of Illness* or the cost borne by an individual for mitigating and averting expenditures and lost time (Cropper and Freeman 1991). See section 2. 1.1 for detailed theoretical review.

from 2001 June to January 2002 is Rs. 4413.71 and Rs. 6273.70 respectively.

- For moderate polluted areas (Irumpanam and Ernakulam North) mean values are Rs. 2997.08 and Rs. 3617.29 respectively.
- WTP for the less polluted area (CSIR and Port Trust) is assumed to be zero as pollution dummy these areas is assumed as zero,.
- Similar trends are noted in the case of median and modal values.

The frequency distribution of sample household's willingness to pay is summarised in table 4.14 below:

Table: 4.14

Frequency Distribution of willingness to pay of sample households in Cochin Industrial Agglomeration

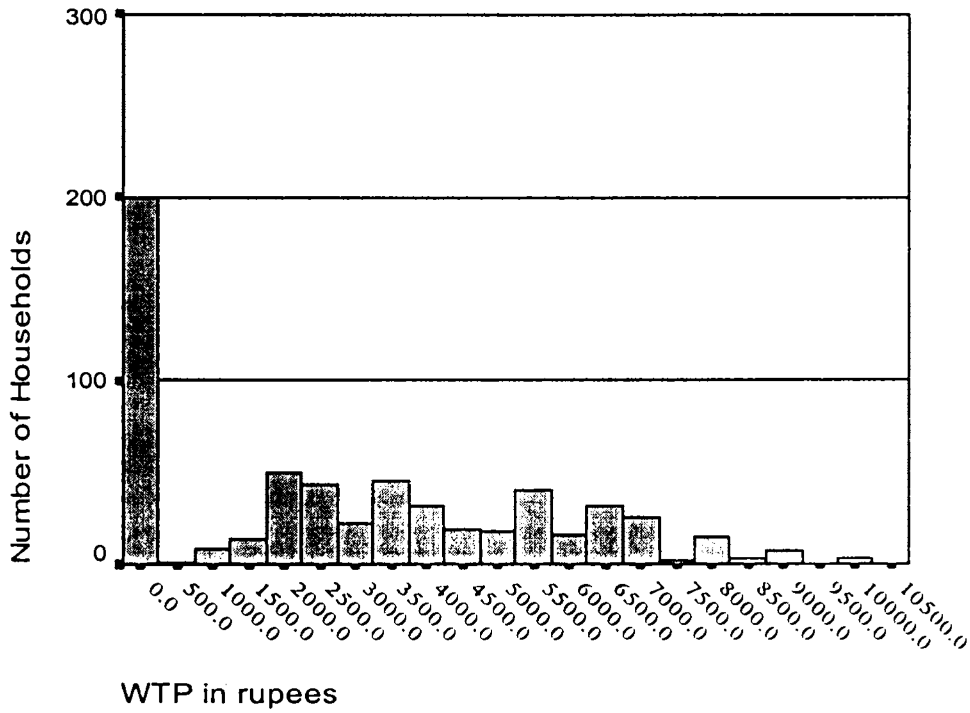
Class	Frequency	Percent
00	200	33.3
500 - 1000	6	1.0
1000 - 2000	52	8.7
2000 - 3000	74	12.3
3000 - 5000	119	19.8
5000 - 7000	102	17.0
above 7000	47	7.8
Total	600	100.0

Source: survey data 2001-02

Graphical representation of the above table is given in figure number 4.1 below:

Figure: 4.1

Histogram of willingness to pay of sample households in Cochin Industrial Agglomeration



This table and chart above shows that:

- Highest percentage (19.8) of the people on the sample households are willing to pay between Rs. 3000-5000.

- On an average, households at cochin industrial agglomeration prefers an average willingness to pay between Rs. 2000 to Rs. 7000, for a period of six months.

4.3.4 Factors Influencing Willingness to Pay

So far, we have estimated the willingness to pay of the sample households, had they been affected by air pollution. Since this measure has been influenced by the environmental and socioeconomic characteristics, a detailed examination of the extent of influence of these variables on the WTP is essential. This is attempted by regressing the estimated WTP values on selected environmental and socioeconomic variables using the method of ordinary least squares.

The regression result is given below in table 4.15

Table 4.15

Results of Regression of Estimated WTP on Selected Environmental and Socio Economic Variables

Dependent Variable: WTP3				
Method: Least Squares				
Sample: 600				
Included observations: 600				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2311.400	251.1152	-9.204544	0.0000
MONTH LY INCOME	0.340920	0.010218	33.36505	0.0000
MTGCOST	0.089587	0.032362	2.768312	0.0058
PDUMMY1	3203.941	92.44630	34.65732	0.0000
PDUMMY2	4946.188	113.2363	43.68023	0.0000
ASTHMA	-18.83137	75.10368	-0.250738	0.8021
BRONCHITIS	-48.08653	92.63681	-0.519087	0.6039
EYE_IRRITATION	-15.02321	80.61985	-0.186346	0.8522
RECFEVER	-37.17153	79.08402	-0.470026	0.6385
EDDUMMY1	-226.4089	122.0652	-1.854819	0.0641
EDDUMMY2	-334.5617	132.1674	-2.531347	0.0116
EDDUMMY3	-290.6264	186.4907	-1.558397	0.1197
SMOKING	-24.16349	76.91624	-0.314153	0.7535
INSURANCE	-93.81452	69.98430	-1.340508	0.1806
AGE	-2.642915	3.436144	-0.769151	0.4421
R-squared	0.903723	Mean dependent var		2883.632
Adjusted R-squared	0.901419	S.D. dependent var		2642.320
S.E. of regression	829.6269	Akaike info criterion		16.30451
Sum squared resid	4.03E+08	Schwarz criterion		16.41443
Log likelihood	-4876.353	F-statistic		392.2286
Durbin-Watson stat	1.738653	Prob(F-statistic)		0.000000

Source: Regression results

It is found that:

- The monthly Income, mitigating cost and pollution dummies had a positive and significant impacts on WTP.

- The pollution coefficients for the moderate polluted areas (Irumpanam and Ernakulam North) showed that people in these areas are willing to pay Rs. 3204 more than those in low polluted areas.

- In highly polluted areas (Ellor and Ambalamugal), people are willing to pay Rs. 4946 at 1% level of significance.

- Monthly income and mitigating costs influence WTP positively.

- All variables other than mitigating cost, monthly income and pollution dummies, showed a negative relationship. However, all, except education dummies, are not statistically significant

In this section so far, we undertook a detailed analysis of the factors influencing the willingness to pay using the household's production function approach and observed that the WTP estimates reflects the social cost of illness However, the expression of WTP given above ignores the social value of averting expenditures and the cost of leisure foregone due to illness (Cropper and Freeman,1991).This necessitates the use of Contingent Valuation Method for eliciting WTP. The next section undertakes this task.

4.4 Contingent Valuation Surveys and Estimation of Willingness to Pay

The contingent valuation method (CVM) is used to estimate values for environmental amenities and other non market goods and services[6]. CVM surveys ask respondents directly about their monetary values for non market goods contingent upon the creation of a market or other means of payment. Therefore all transactions are hypothetical (Bishop *et al*, 1995). In this study, Contingent Valuation surveys were organised to measure the willingness to Pay directly[7]. As part of the study, a survey was conducted on a representative sample of 600 households in six selected centres. The purpose of the survey was to elicit their willingness to pay (WTP) to avoid additional 'symptom days'. First, people were asked to reveal their judgement on air pollution in the area. They were then asked about their health status and Restrictive Activity Days (RAD) due to pollution. They were also asked about the averting and mitigating activities and the respective costs for avoiding illness during the last six months. Data on socio economic and demographic variables such as, income, education, age, habits etc, were collected as part of the survey. After describing the exposure response relationship, with the

---

[6] WTP is estimated from defensive expenditures and other socio economic variables in the health production function approach, while, the Contingent Valuation Method (CVM) involves asking people either what they would be willing to pay to reduce symptoms corresponding to a change in pollution. 'This method presents respondents with a detailed scenario of the hypothetical market and of public good in question (including the nature of the benefits it would confer on the respondent), and then directly asks respondents to state how much they would be willing to give up (pay) in order to enjoy benefits they would derive if the public good were provided' (Murty and Markandya, 2000). "The contingent valuation method (CVM) is used to estimate values for environmental amenities and other non market goods and services. Surveys are used to ask respondents about their monetary values for non market goods contingent upon the creation of a market or other means of payment." (Bishop *et al*, 1995).

[7] See section 2.1 for detailed theoretical issues.

help of other studies, like Kerala Shastra Saahitya parishat, Green Peace, Pollution Control Board etc. sample households were reminded about possibilities of preventive expenditures and reductions in their budget. Then the individuals were asked whether they would be willing to pay Rs. 200. The bids were raised for positive answers up to Rs. 3500And lowered, if the answer was negative.

Area-wise WTP values[8] per household from the CVM survey is given in table 4.16 below.

Table: 4.16

Distribution of Willingness to Pay of the residents of Cochin Industrial Agglomeration to Avoid 'Symptom Days Using Contingent Valuation Survey 2001-2002

	N	Minimum	Maximum	Mean	Median	Mode	Std. Deviation
ELOOR	100	00	3500	932.00	600	600	822.18
Irumpanam	100	00	3000	552.50	450	00	504.09
CSIR	100	00	1500	359.50	400	00	300.90
Port trust	100	00	1250	481.00	500	500	308.37
AMBALAMUGAL	100	00	2800	1059.00	1000	1000	592.73
EKM North	100	00	2500	636.25	500	500	458.91
WTTP	600	00	3500	670.04	500	500	581.85

Source: Survey data

[8] One strategy to check the validity of CVM is to develop different scenarios to test hypothesis about the effects of the mean values of the Sample (Freeman, 1993). This test can be evolved by combining mean responses across the sample groups given in different scenarios, which is provided by different environmental characteristics. The sample mean varies in a consistent fashion with relevant and meaningful variations in the scenario.

The CVMsurvey reveals that

- Mean WTP to avoid symptom days in high polluted areas (Eloor and Ambalamugal is greater than moderate (Irumpanam and Ernakulam North) and less polluted areas (CSIR Complex and Port Trust).

- For instance, highly polluted areas (Eloor and Ambalamugal) the mean WTP values are Rs. 932 and Rs. 1059 respectively.

- For moderate polluted areas (Irumpanam and Ernakulam North) mean WTP values are Rs. 552.50 and Rs. 636 respectively.

- For less polluted areas (CSIR Complex and Port Trust) the respective mean WTP values are Rs. 359 and Rs. 481.

The frequency distribution of the WTP of the residents of Cochin industrial agglomeration for avoiding symptoms days is given in table 4.17 below.

Table: 4.17

Frequency distribution of WTP

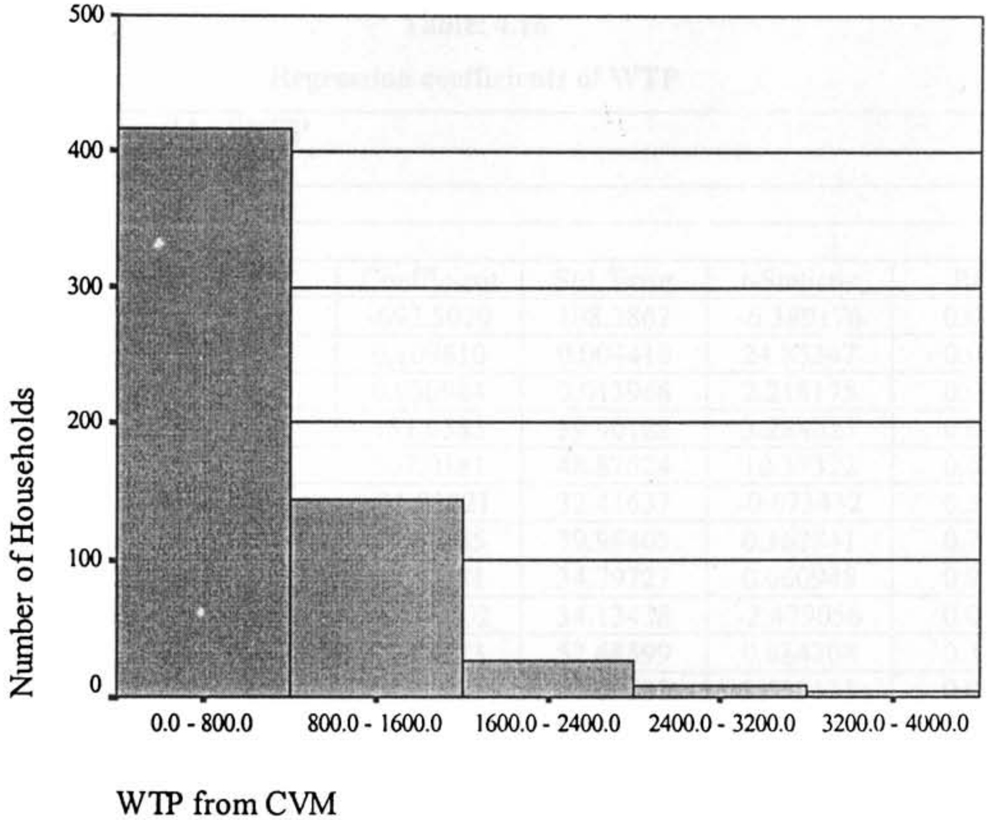
WTP (in Rs.)	Frequency	Percent
Less than 200	81	13.5
200 - 500	243	40.5
500 - 1000	173	28.8
1000 - 1500	64	10.7
1500 - 2000	24	4.0
More than 2000	15	2.5
Total	600	100.0

Source: survey data 2001-02

Graph of the table 4.18 is given below:

Figure: 4.2

Distribution of WTP from CV survey



The table and the chart reveal that:

- Around 83 percent of the respondents were willing to pay an amount less than Rs. one thousand to avoid symptom days. The highest percentage, 28.8 are willing to pay a sum of Rupees between 500 and 1000.

In order to verify the influence of environmental and socio economic variables on the respondent's willingness to pay (WTP), the elicited willingness to pay (WTP) bids were regressed on these variables. The regression result is given below in table 4.18

Table: 4.18

Regression coefficients of WTP

Dependent Variable: WTTP				
Method: Least Squares				
Sample: 1 600				
Included observations: 600				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-692.5020	108.3867	-6.389176	0.0000
MONTHLY INCOME	0.109610	0.004410	24.85347	0.0000
MTGCOST	0.030984	0.013968	2.218175	0.0269
PDUMMY1	131.0385	39.90182	3.284023	0.0011
PDUMMY2	507.0181	48.87524	10.37372	0.0000
ASTHMA	-21.83021	32.41637	-0.673432	0.5009
BRONCHITIS	14.48385	39.98405	0.362241	0.7173
EYE_IRRITATION	2.120831	34.79727	0.060948	0.9514
RECFEVER	-84.62102	34.13438	-2.479056	0.0135
EDDUMMY1	46.61173	52.68599	0.884708	0.3767
EDDUMMY2	144.8482	57.04632	2.539133	0.0114
EDDUMMY3	80.44716	80.49340	0.999425	0.3180
SMOKING	-69.35044	33.19872	-2.088949	0.0371
INSURANCE	45.41080	30.20674	1.503333	0.1333
AGE	3.141314	1.483114	2.118052	0.0346
R-squared	0.630106	Mean dependent var		670.0417
Adjusted R-squared	0.621254	S.D. dependent var		581.8515
S.E. of regression	358.0849	Akaike info criterion		14.62410
Sum squared resid	75011519	Schwarz criterion		14.73402
Log likelihood	-4372.230	F-statistic		71.18112
Durbin-Watson stat	1.762449	Prob(F-statistic)		0.000000

Source: Regression results

The estimates indicate that:

- Monthly income, mitigating cost, pollution dummies and education dummy1 have positive and significant impact on willingness to pay (WTP)Income is highly significant and is positively related to the willingness to pay (WTP) of the people, that is, unit increase in income increase willingness to pay (WTP) by 10 percent.

- Mitigating cost has also positive impact on willingness to pay (WTP) and is significant at 2 percent level.

- Coefficients of pollution dummy shows that people in the moderate polluted areas were willing to pay Rs.131 more than those in low polluted areas.

- In high polluted areas residents were willing to pay Rs. 507 more than those in the low polluted areas. Both the coefficients are significant at 1 percent level.

- Except recurrent fever, all other coefficients of disease were not statistically significant and are negatively related to willingness to pay (WTP).

- Among the education dummy, all coefficients except graduate class were statistically insignificant.
- Coefficients of smoking and age are significant at a level of 3 percent. Coefficient of smoking is negatively related while age and insurance are positively related.

4.5 WTP from Household Production function and Contingent Valuation Survey Approaches: A Comparison

In order to assess the validity[9] of CVM results, two approaches are generally suggested in the literature[10]. The former involved a careful assessment of the survey instrument and scenario to verify whether all known sources of bias had been removed or avoided. The other strategy suggested a comparison of the empirical analysis and results of WTP estimates from alternate methods (Freeman, 1993). In this study, however, our strategy is to compare WTP values derived

---

[9] The validity of any piece of hypothetical data is the degree to which it measures the theoretical construct of interest. The theoretical construct of interest is the individual's true value, true probability of accepting an offer, true ranking of alternatives or true change in the level of activity. If one would like to asses the validity of a hypothetical value, compare it with the true value (Freeman, 1993)

[10] The CVM has two advantages over indirect methods. First, it can deal with both use value and non-use values, where as indirect methods cover only the former and involve weak-complementarily assumptions. Secondly, CVM answers to WTP questions go directly to the theoretically correct monetary measures of utility changes. However, the accuracy of CVM has been debated by many scholars. Preferences revealed through actual behaviour have great credibility in economics. However, statements by economic actors about how they would act under hypothetical situations are to be viewed with great suspicion (Bishop, Richard *et. al, op. cit* 1995). There are several issues that arise in examining CVM studies. Many early studies using CVM were concerned with the large number of bias that could result from using this method. Mitchell and Carson (1989) give a comprehensive account of biases in CVM. 'Bias' means a systematic over or under statement of true WTP. The possible sources of such bias include the starting point in bidding games (Boyle et al., 1986), the choice of bid vehicle (Rowe et al., 1980), and hypothetical market bias (Bishop and Heberleine, 1979). Another area of concern is strategic bias. If respondents believe that bids will be actually collected, they may understate their WTP for a welfare improving change because environmental goods are typically non excludable in consumption (Hanley, Shogren and White, 1997). Another issue related to the examination of CV studies is how to value the commodity, such as the reduction of symptom days. A second issue common to all CVM studies is whether the respondents carefully consider the budgetary implications of their responses. Mitchell and Carson (1989) explain validity and apply it to CVM in this way: '*the validity of a measure is the degree to which it measures the theoretical construct under investigation. This construct is in nature of things, unobservable; all we can do is to obtain imperfect measures of that entity. In the Contingent Valuation context the theoretical construct is the maximum amount of money the respondents would actually pay for the public good if the appropriate market for the market good existed.*'

through contingent surveys with measures derived from the production function estimates(Brookshire et al. ,1982) compared CV measures of the value of improved air quality with values derived from production function model[11]. A comparison of WTP estimated from both approaches is given in table 4. 19.

Table: 4. 19

WTP Estimates from Household Production Function and Contingent Valuation survey Approaches.

STATIONS	Production function	CVM
ELOOR	4413.71	932.00
Irumpanam	2997.08	552.50
CSIR	00	359.50
Port trust	00	481.00
Ambalamugal	6273.70	1059.00
EKM North	3617.29	636.25
WTP Whole Sample	2883.63	670.04

Source: Survey data, 2001-02

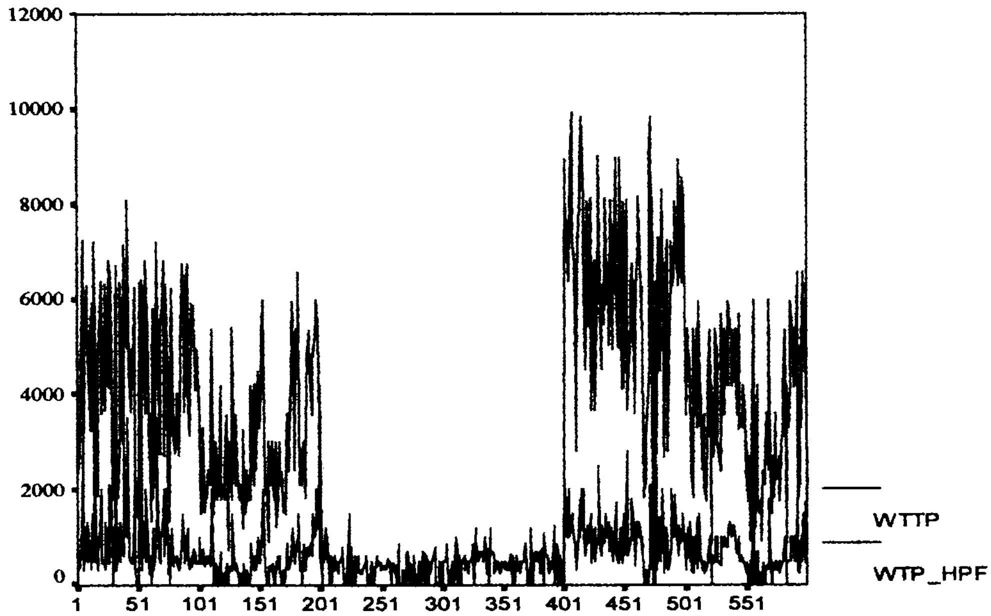
[11] An important difference between WTP from production function approach and CVM approach is that in CVM, WTP is a function of total derivative of illness with respect to pollution, $\partial S / \partial C$ which incorporates effects of pollution on defensive behavior to illness. To compare $\partial S / \partial C$ under CVM, it is not necessary to estimate the Household production function, rather it is possible to estimate a dose-response function which is a reduced form of relationship between illness, ambient air quality and variables that affect defensive expenditures. In a household production function, dose response function is obtained by substituting the demand functions for mitigating activities in to the household production function (Cropper and Freeman, 1991).

From the table above, it is observed that willingness to pay (WTP) values in both the household production function and contingent valuation survey approaches are higher in Ambalamugal and Ellor, respectively, which were considered as highly polluted areas. ErnakulamNorth and Irumpanam showed moderate willingness to pay (WTP) values compared to less polluted areas. In both the approaches, it is seen that willingness to pay (WTP) values are greater in highly polluted areas while they are lower in less polluted areas.

A comparison of WTP estimated from both approaches with the help of a sequence chart is given in figure 4.3 below.

Figure 4.3

Comparison of WTP estimates from Household Production Function (WTP_HPF) and Contingent Valuation (WTTP) surveys



Sequence chart for WTP from direct CV survey is denoted by WTTP and the WTP CHART estimated from health production function is denoted by WTP_HPF. It is clear from the chart that

- Both WTTP and WTP_HPF are moving in the same direction and in the same pattern. There is a gap in the WTP_HPF line because WTP in the base pollution dummy (low polluted area) is assumed to be zero.

- Willingness to pay estimates for production function is higher than the willingness to pay estimates directly collected from the market. This could be explained by the possibility of existence of strategic bias, in CVM, in which case, the respondents may under state their WTP due to the common good nature of air quality.

The above analysis reinforces the validity of our approaches for estimating the household's willingness to pay to avoid symptom days in Cochin industrial agglomeration in Kerala.

4.6 Summary and Conclusions

In this Chapter, we made an attempt to estimate the willingness to pay for avoiding 'symptom days' of selected households in the study area. This is calculated using the household production function and contingent valuation approaches. In the former approach, willingness to pay was estimated in a two stage regression analysis. The results showed that the coefficient of air pollution is positive and highly significant to doctor visits and restrictive activity days. The average WTP for the highly polluted areas of the Cochin industrial agglomeration, for the six months from December 2001 to June 2002 were Rs. 4413.71 and Rs. 6273.70 respectively. For moderate polluted areas these values were Rs. 2997.08 and Rs. 3617.29 respectively, showing clear evidence that average willingness to pay is positively influence by air pollution. It is also observed that monthly income and mitigating cost have positive and significant impacts on WTP.

Under CVM approach, WTP is estimated by directly asking people how much they are willing to pay to reduce pollution. The major results provided by the analysis were the average WTP to avoid symptom days in high polluted areas is greater than moderate and less polluted areas. In highly polluted areas the mean WTP values are Rs. 932 and Rs. 1059 respectively, while in moderate polluted areas these values are Rs. 552.50 and Rs. 636 and in less polluted areas were Rs. 359 and Rs.481, respectively. In general, the two approaches provide evidence that households in the Cochin Industrial Agglomeration value health reduction due to change in air quality.

Then for testing validity the two approaches were compared and found that the both methods generating similar results. It is hence observed that the CV surveys can be successfully conducted in cities of developing countries. From a policy perspective, the results can be used to frame appropriate compensation strategies. In short, this chapter provides two sets of evidence. First, the mean WTP for high and moderate polluted areas are different as per the changes in the level of pollution. The second set of evidence comes from the estimated household production function model, where doctor visits and restricted activity days have significant positive coefficient on two pollution dummies.

Chapter 5

Economic Impacts of Air Pollution on Property Values

In the previous chapter we discussed how pollution impinges on the health of local population. We argued that the affected target groups in the study area undertake a variety of measures to avoid morbidity. The willingness to pay estimates not only reflected the behaviour of local households towards this aversive behaviour but even provided significant directive for designing pollution abatement initiatives. We also mentioned that in addition to the negative influences on the health of the people, air pollution also affects the productivity and price of land which has everlasting consequences to crop production, settlement patterns and the growth of urban property market. The local population, the real estate/ housing enterprises and related industries in Cochin had already started responding to this deterioration in various ways[1]. An examination of how air quality deterioration influences residential property values is therefore essential. In this chapter we will analyse the relationship between air pollution and property prices in the Cochin industrial agglomeration. This chapter is divided into 6 sections. In section 1 we present a detailed description of how air pollution and property prices are related. Section 2 presents the hedonic price model, which is used to estimate this relationship.

[1] Various local level institutions and NGOs such as Kerala Shastra Sahitya Parishat, Greenpeace and various local people's organisations have raised voices on a number of serious environmental issues. During the last few years, these issues have been reflected in a number of environment-livelihood related agitations and protest movements in various parts of the State.

Section 3 deals with the data base and section 4 details the estimation of the model. Discussions of the results of the model are provided in section 5. The last section gives a summary of this chapter

5.1 The Influence of Pollution Articulated Through Property Prices

Residential property prices have increasingly been influenced by the quality of air and its deterioration therefore, affects urban property values. In most of the industrial cities the world over, consumers express their strong preference for environmental amenities such as improved air quality and are even willing to pay for such improvements. Consumer's WTP in turn has been influenced by structural characteristics like size of the plot, number of rooms, garage space, central heating, structural integrity etc., public and local socio economic characteristics like social security, quality of schools, racial composition, rate of employment, wage differentials, taxes etc. and local amenities like environmental quality, access to services, communications etc (Parikh, *et al.*, 1994; Garrod, 1999; Mahan *et al.*, 2000; Murty and Surendar Kumar, 2002). Although all these factors influence the choices of consumers, the primary concern of this inquiry is to unearth how the quality of air influences property values.

The hedonic pricing method (HPM) uses a related market approach to obtain the value of an environmental amenity from indirect observations (Rosen, 1974). Economic theory argues that in certain circumstances, it is possible to separate the effects of various attributes of a good in ways by which they influence individual's utility. For many environmental goods, it is often possible for individuals to choose levels of consumption through their choices. For instance, in a decision to buy a home, there is an implicit market for environmental quality. The demand for non market environmental goods such as air quality influences observed prices and consumption of other market goods. The most commonly applied model to quantify this relationship is the hedonic price model of environmental valuation. The next section details the basic model to study how pollution depresses property values.

5.2 Theoretical Model

The hedonic price technique is a method for estimating the welfare effects of environmental assets and services by estimating the influences of environmental attributes on property value. The hedonic price theory assumes that as environmental quality changes, property prices would also change, indicating a scope for estimating an implicit demand function for the environmental goods by observing the property price variations. So hedonic prices are defined as the implicit prices of the attributes and are revealed to economic agents from observed prices of differentiated products and the specific amounts of characteristics associated with them (Banarjee, S. in Bhattacharya, 2002).

Following the general principles of consumer's behavioural theories, decisions in property markets are governed by demand supply interactions. The basic hedonic property model can be explained as given below.

Let the price of i^{th} residential location (Phi) be

$$Phi = Ph(Si, Ni, Qi) \quad \text{-------------------- (1)}$$

where,

S_i is structural characteristics
N_i is neighbourhood characteristics
Q_i is environmental characteristics

Consider the utility function of the individual who occupies house i as

$$u(X, Si, Ni, Qi) \quad \text{--------------------- (2)}$$

where, X represents composite private good that is taken as a numeraire. Assume that preferences are weakly separable in housing and its characteristics. The individual maximizes (2) subject to the budget constraint,

$$M = X + Phi \text{------------------------------ (3)}$$

the first order condition for the choice of environmental amenity qj is given as,

$$\frac{\partial u / \partial qi}{\partial u / \partial x} = \frac{\partial Phi}{\partial qj} \text{ ---------------------------- } (4)$$

The partial derivative of (1) with respect to one of the environmental quality characteristics *qj*, (air quality), give the implicit marginal price of that characteristic.

In the second stage, MWTP for environmental quality is expressed as a function of *qj*, given *Si, Ni, Qi** and *Gi*, where *Qi** ins the vector of other environmental characteristics and *Gi* is socio- economic characteristics.

$$bij = bij(qj, Qi^*, Si, Ni, Gi) \text{ -------------------- } (5)$$

Equation (5) gives the individual's MWTP for the improvement in environmental quality *qj*. If there is an improvement in environmental characteristic from qj^0 to qj^1, the value individuals place on such improvement (*Bij*) could be estimated by integrating (5) with respect to *qj*.

$$Bij = \int_{qjo}^{qj1} bij(qj, Qi^*, Si, Ni, Gi)\partial qj \text{ -------------- } (6)$$

The value obtained by integrating the inverse demand function with respect to the implicit price is interpreted as the consumer surplus.

5.3 The Database

In order to estimate a hedonic price function, it is necessary to gather data on all characteristics that are relevant to choices including the sales prices of the house. The explained variable, price of the house, is considered as a function of environmental, structural and neighbourhood variables and these data sets relate to the residential areas of Cochin industrial agglomeration, Kerala, India. Data from 600 households were collected using a structured questionnaire[2].

(a) Sales price of Residential Property

The sales price of land, the dependent variable in the hedonic price function, is the sum of the value of the residence and land.[3] The distribution of sales price of residential property in the study area is given in table 5.1

Table: 5.1

Distribution of Prices of Residential Property

Value (in Rs.)	Frequency	Percent
0-100000	4	0.7
100000-300000	175	29.2
300000-600000	203	33.8
600000-900000	70	11.7
900000-1200000	35	5.8
>1200000	113	18.8
Total	600	100.0

Source: survey data, 2001-02

[2] See chapter 1 section 1.5 for details on data collected

[3] Since, the data published by the Revenue Department of the State is a broad underestimate, the actual sales price of land is collected through the primary survey. It is then cross examined for reliability by comparing to the near residential price.

Table 5.2 shows that more than 63 percent of the households own property, the value of which lies between 1 lakh and 6 lakhs; around 18 percent has a value between 6 lakhs and 12 lakhs and 19 percent has property values above 12 lakhs[4].

Among the independent variables, area of the residential property is a structural variable and its distribution is given in Table 5.2.

Table 5.2

Distribution of Residential Plot by Size

Plot area (in Cents)	Frequency	Percent
0-5	122	20.3
5-10	260	43.3
10-15	117	19.5
15-20	46	7.7
20-40	31	5.2
40-70	5	.8
70-100	8	1.3
Above 100	11	1.8
Total	600	100.0

Source: survey data 2001-2002

The above table clearly shows that around 83 percent of the households in the area own residential property below 15 cents; Only 11 households (1.8 percent) have occupied land above one acre.

[4] However, the average sales price was different in different regions. See section 3.3, chapter 3 for details regarding study area.

(a) Air Quality (SO_2)

In the hedonic price model that we adopt in this analysis, the concentration of SO_2 is taken as the measure of air quality. The data used comes from the ambient air quality monitoring statistics of the Central Pollution Control Board. Ambient air quality for the year 2000 for various monitoring stations of Cochin is given in table 5.3 below.

Table: 5.3

Distribution of the Average Concentration of SO_2 by Stations

Location	**$SO_{2\,(unit)}$**
Eloor	**122.6**
Irumpanam	**159.6**
ENM north	103.6
Port trust	66
CSIR complex	44.2
Ambalamugal	98.2
Tolerence (Residential)	60 – 90
Tolerence (Industry)	80-120

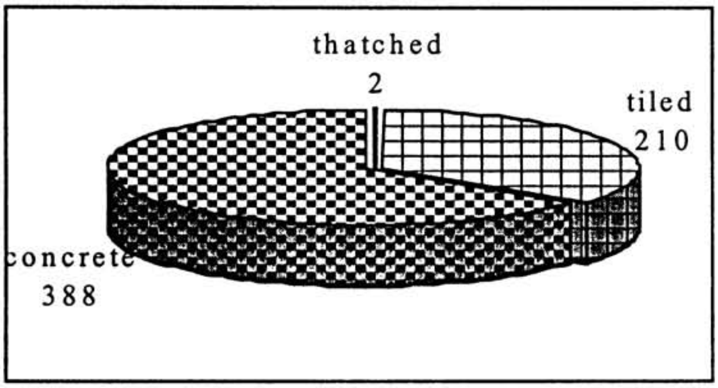
Source: survey data, 2001-02

Irumpanam shows high concentration of SO_2, while CSIR complex recorded the lowest levels of SO_2. Except Port Trust and CSIR complex, all other locations have concentrations of SO_2 higher than the upper limits of residential tolerance levels. For both Eloor and Irumpanam average concentration of SO_2 is more than the maximum of industrial tolerance level.

(b) Type of House

House type is another important variable affecting the price of residential property. Type of house is divided into three – thatched, tiled and concrete. Concrete houses have a high value followed by tiled and thatched. Land price therefore varies accordingly. The survey recorded the highest percentage (67.4) of concrete houses while tiled houses accounted for only 35 percent. (See the Pie diagram 5.1 below).

Figure: 5.1
Type of House

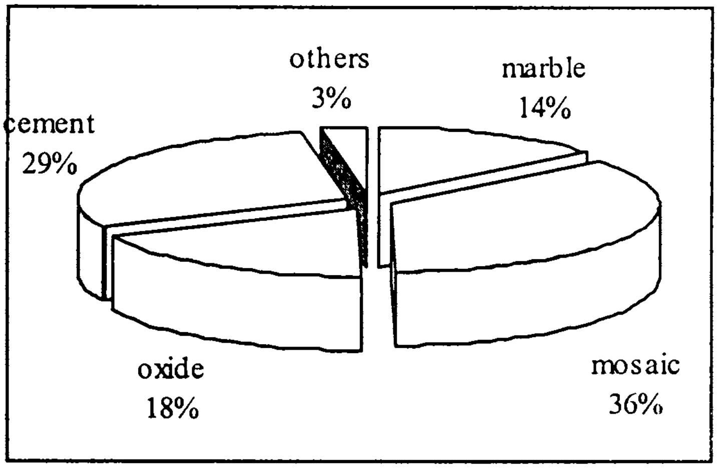


Source: survey data, 2001-02

(c) Type of Floor

Floor type is another important variable which influences residential property prices significantly. Floor type is divided in to five categories - marble, mosaic, oxide, cement and others. Marble is highly valued followed by other categories. Figure 5.2 shows a Pie diagram for floor type. As is evident from the figure, 35. 7 percentage of houses have mosaic flooring, 29.3 percent have cement flooring and 18 percent have oxide finishing.

Figure 5.2
Type of Floor



Source: survey data, 2001-02

(d) Area of House

Area of house is another important variable affecting house prices. Frequency distribution for area of house in the sample is given in table 5.4 below:

Table: 5.4
Distribution for Residential Houses by Size

Area (square feet)	Frequency	Percent
0-500	14	2.3
500-1000	182	30.3
1000-1500	265	44.2
1500-2000	129	21.5
>2000	10	1.7
Total	600	100.0

Source: survey data, 2001-02

The table reveals that around 95 percent of households in the agglomeration occupied houses of area between 500 and 2000 square feet. Only 10 (1.7 percentage) occupy houses with plinth area more than 2000 square feet.

(e) Number of Rooms

Another factor which influences residential property price is the number of rooms that a house has. Average number of rooms observed for houses in the study area is eleven. Around 38 percent of houses have less than 3 rooms. Frequency distribution of number of rooms is given in table 5.5 below.

Table 5.5

Distribution of Residential Houses by Number of Rooms

No. of Rooms	Frequency	Percent
Less than 3	226	37.7
3 - 6	351	58.5
6 - 9	20	3.3
More than 9	3	.5
Total	600	100.0

Source: survey data, 2001-02

It is evident from the data presented above that 58.5 percent of households occupy houses with rooms between 3 to 6, followed by 37.3 percent occupying less than 3 rooms. Less than 4 percent of the people occupy houses with more than 6 rooms.

(f) Number of Toilets

The data on the number of toilets, another important variable in the analysis is given in table 5.6.

Table: 5.6

Distribution of Residential Houses by Toilets.

No of toilets	Total	%
1	210	35
2	232	38.66
3	92	15.33
4	61	10.16
5	5	0.83
Total	600	100

Source: survey data, 2001-02

The table above reveals that around 74 percent of the households in the study area live in houses with two or less than two toilets. A very minor percent (0.83) have more than 5 toilets.

(g) Distance from city and industry

Among the 'neighbourhood variables', two major ones - distance from the city and distance from industrial place - are also considered for this analysis. Distance calculated is that from the residence of the household to the nearest city station. Ernakulam North and South are the stations considered for measuring distance from city. 100 (16.7 %) households are residing with in the limit of the city, hence their distance is considered as zero. In the case of distance from industry, 13.6 percent of people are staying with in the industrial limits. 83.35 percent of households reside within five kilometers of the industrial limit.

(h) Availability of external facilities

Four variables are considered under this category – availability of electricity, passage to home, fencing and water. It is observed that when these facilities increase, house and property price will also increase. Availability of these factors is given in the table 5.7 below:

Table: 5.7
Availability of External Facilities

Facilities	YES	%	NO	%
Electricity	595	99.2	5	0.8
Passage	558	93	42	7
Fencing	516	86	84	14
Water Availability	579	96.5	21	3.5

Source: survey data, 2001-02

Table above clearly indicates that a very big percent of the households in the study area are enjoying external facilities, such as, electricity, passage, fencing and water availability. Only five (0.8 percent) residential households in the sample do not have electricity connection. The major sources of water in the sample area are Wells and piped water connection.

(i) Age of House

Frequency distribution for age of house is given in table 5.8 below:

Table: 5.8
Age of House

year	Frequency	Percent
0-5	97	16.2
5-10	136	22.7
10-20	168	28.0
20-30	145	24.2
30-50	51	8.5
>50	3	.5
Total	600	100.0

Source: survey data, 2001-02

A large number of houses in the area are constructed within the last 50 years. Majority of the houses (75 percent) in the sample are in the age group between 5 and 30.

(j) Duration of stay

Frequency distribution for duration of stay is given in table 5.9 below.

Table: 5.9
Duration of Stay

year	Frequency	Percent
0-5	109	18.2
5-10	143	23.8
10-20	197	32.8
20-30	117	19.5
30-50	31	5.2
>50	3	.5
Total	600	100.0

Source: survey data, 2001-02

The table above reveals that the major category, (32.8 percent) of households have been staying in the present residence for the past 10 to 20 years followed by 23.8 percent for the last 5-10 years. A large majority of households (94 percent) have been staying in the present house for the past 30 years.

With the help of the above data set, the marginal implicit price of residential property for Cochin is calculated as follows.

5.4 Estimation of the Model

Estimation of the hedonic model was undertaken in two stages (Rosen, 1974; Freeman, 1979). In the first stage, the hedonic property price function was estimated and the implicit prices were computed for all the observations. In the second stage, implicit demand function or the marginal willingness to pay function was derived from the hedonic price function for given sets of environmental characteristics. The procedure is explained below.

5.4.1 Specification of the Hedonic Price Function

The hedonic price function relates sales price of residential property to the structural, neighbourhood and environmental characteristics of the property (Murty, 2002) and is estimated using a simple least square regression model.[5] Following this general specification and refining it by dropping insignificant variables, the hedonic price function is estimated as follows.

---

[5] The model is specified as follows:

$$LnPh_i = \beta_0 + \sum \beta_j S_{ij} + \sum \beta_k Q_{ki} + \sum \beta_l N_{li} + \varepsilon_i,$$

Where, $i = 1, 2, \ldots n$

S_i is structural characteristics

N_i is neighbourhood characteristics

Q_i is environmental characteristics

From the above hedonic price function, implicit price(s) of environmental characteristic (s) is calculated. First partial derivative of the hedonic price function with respect to environment quality provides the implicit price.

$$\ln priceh = \alpha_0 + \alpha_1 \ln trees + \alpha_2 \ln plotarea + \alpha_3 hstypdum + \alpha_4 \ln area + \alpha_5 \ln discit + \alpha_6 \ln dis\_ind + \alpha_7 \ln SO_2 + \varepsilon$$

where,

Variable name	Description
$\ln priceh$	Natural log of property price
$\ln trees$	Natural log of number of trees
$\ln plotarea$	Natural log of plot area
$\ln area$	Natural log of plinth area of house
$\ln discit$	Natural log of distance from city
$\ln dis\_ind$	Natural log of distance from industry
$\ln SO_2$	Natural log of SO_2
hstypdum	Dummy variable for type of house

The partial derivative of this function with respect to air quality gives its implicit marginal price. This price is the additional amount which the household would be willing to pay for choosing a house with reduced amounts of air pollution, other things remaining the same. The marginal implicit price is estimated as follows.

$$implicit\ price = priceh.\left(\frac{1}{SO_2}\right).\alpha_7$$

5.4.2 Specification of the Implicit Demand Function

Estimated implicit prices for different sites correspond to the individual willingness to pay (WTP) for a marginal unit of environmental good purchased. The individual chooses the level of characteristic at which their Marginal Willingness to Pay (MWTP) for that characteristic is equal to its implicit marginal price. The inverse demand function is then obtained by regressing implicit price as a function of air quality, SO_2, and other socio economic features of individuals along with a demand shift variable, such as, income. The regression equation for inverse demand function in general is:

$$\ln imprice_{i} = \beta_0 + \beta_1 Y + \sum \beta_j G_{ij} + \sum \beta_k S_{ik} + \sum \beta_l N_{il} + \sum \beta_m Q_{im} + \varepsilon ,$$

Where,

Y is the annual income of the house hold,

G_i is the socio economic characteristics

S_i is the structural characteristics

N_i is the neighbourhood characteristics

Q_i is environmental characteristics

However, if some or many of the structural characteristics were not significant, these factors could be neglected while specifying the relation. So after omitting the insignificant variables through trial and error method, the implicit price function considered for final estimation is:

$$\ln imprice = \beta_0 + \beta_1 \ln anlinc + \beta_2 \ln fmemb + \beta_3 \ln ptarea + \beta_4 \ln discit + \beta_5 \ln dis\_ind + \beta_6 \ln SO_2 + \varepsilon$$

Where,

Variable name	Description
ln *imprice*	Natural log of implicit price
ln *anlinc*	Natural log of annual income
ln *fmemb*	Natural log of family members
ln *plotarea*	Natural log of plot area
ln *discit*	Natural log of distance from city
ln *dis_ind*	Natural log of distance from industry
ln SO_2	Natural log of SO_2

5.5 Empirical Results and Interpretation

5.5.1 Hedonic Price Equation

In the estimation of hedonic price equation, we assume a negative relationship between environmental characteristic SO_2 and the land price, where as, number of tree coverage is assumed to have a positive influence. All the structural parameters included in the model, like plot area, type of house, etc are expected to have positive relations with the property price. Neighbourhood characters like distance from industry and city are inversely related with pollution. It is normally expected that as distance from city increases property price decrease, where as distance from industrial location increases, property price also increases. Applying these assumptions on the model specified above, the parameters are estimated using the method of ordinary least squares and is given in table 5.10 below.

Table: 5.10
Regression Results of Hedonic Price Function

Dependent Variable:ln*priceh*				
Predictors: LNDISIND, HSTYPDUM, LNPTAREA, LNSO2, LNDISCIT, LNAR LNTREES				
Included observations: 600				
Method: Ordinary Least Squares				
	Un standardized Coefficients *B*	Std. Error	t	Sig.
(Constant)	13.958	.329	42.366	.000
LNSO2	-0.456	.034	-13.568	.000
LNTREES	2.502E-02	.014	1.727	.085
LNPTAREA	0.775	.020	38.090	.000
HSTYPDUM	-2.566E-02	.029	-.890	.374
LNAREA	-3.953E-02	.044	-.894	.372
LNDISCIT	-.312	.010	-32.235	.000
LNDISIND	.210	.013	16.714	.000
R	*R^2*	*Adjusted R^2*	*Std. Error of the Estimate*	
0.936	0.875	0.874	0.3039	

	Sum of Squares	df	Mean Square	F	Sig.
Regression	377.513	7	53.930	583.901	.000
Residual	53.847	583	9.236E-02		
Total	431.361	590			

Source: survey data, 2001-02

The main inferences of this analysis are given below:

- All the neighbourhood and structural characteristics except house type and plinth area are not statistically significant at 15 percent level of significance.

- The environmental characteristic, SO_2, is negatively related to house price and it is significant at 1 percent level. The results also confirm that as the level of SO_2 increases by one percent house price reduces by 0.45 percent on the average.

- Among the neighbourhood characteristics, tree coverage is positively related to property price.

- Distance from city is negatively related to house price, showing that the plots nearer to the city have high property values.

- Distance form industry is positively related, showing that when distance increases, property prices also increase.

- Total area of the plot is also positively related to property value.

The regression results of the hedonic price function shows that all the significant estimated variables follow the expected relationship patterns. Hence the estimated equation could be written as:

$$\ln priceh = 13.958 + 2.502E^{-02} \ln trees + 0.775 \ln plotarea - 2.566E^{-02} hstypdum$$
$$- 3.953E^{-02} \ln areal - .312 \ln discit + .210 \ln dis\_ind - 456 \ln SO_2 + \varepsilon$$

5.5.2 Calculation of Implicit Marginal Price

The first derivative of the hedonic price function can be interpreted as the implicit marginal price function for the environmental good. Descriptive statistics of implicit prices for 600 observations is given in table 5.11 below:

Table: 5.11
Descriptive Statistics of Implicit Prices

Descriptive statistics	*Implicit price* (in Rs.)
Mean	5154.26
Standard Error	382.92
Median	2553.97
Mode	8290.91
Standard Deviation	9379.52
Skewness	7.97
Minimum	285.71
Maximum	148251.60
Count	600.00
Confidence Level(95.0%)	752.02

Source: Source: survey data, 2001-02

Hence the marginal implicit price for reducing SO_2 is calculated as Rs. 5154. This result clearly identifies air quality as an important factor, along with structural and neighbourhood characteristics, in determining demand for land transactions in Cochin.

5.5.3 Implicit Demand Function

As mentioned earlier, second stage estimation of inverse demand curve is done by regressing the implicit marginal price on the quantity of environmental good purchased and other socio economic features including income of the individuals. The results are given in table 5.12 below:

Table: 5.12
Estimation of Inverse Demand Function

Dependent Variable: LNIMPLPR				
Predictors: LNDISIND, LNANLINC, LNFMEMB, LNPTAREA, LNDISCIT, $LNSO_2$				
Included observations: 600				
Method: Ordinary Least Squares				
	Coefficients B	Std. Error	t	Sig.
(Constant)	13.065	.391	33.415	.000
LNANLINC	-2.203E-02	.028	-.783	.434
LNFMEMB	.152	.050	3.059	.002
LNSO2	-1.488	.032	-45.953	.000
LNPTAREA	.785	.018	43.343	.000
LNDISCIT	-.303	.009	-35.209	.000
LNDISIND	.211	.011	18.765	.000
R	R^2	*Adjusted R*	*Std. Error of the Estimate*	
.961	.923	.922	.3010	

Source: survey data, 2001-02

The major inferences are:

- The first derivative of the implicit marginal price function with respect to SO_2 is negative (-1.488) signalling decreasing marginal implicit prices for increasing environmental quality. That means that in the study area, a reduction in SO_2 by one percent leads to 1.48 percent increase in property values.

- The coefficient of income is not significant.

- All other variables except annual income are significant at 1 percent level of significance. It is interesting to note that as the distance increases by one percent from the polluting industries, residential property value enhances by 0.21 percent. And finally,

- Plot area is positively related to residential property values.

So far we have explained the hedonic price function estimation and its implications to residential property values. The results indicate very clearly that the households are willing to pay for improved air quality. It is therefore necessary to estimate the welfare benefits accruing to them through the purchase of property with reduced air quality. We shall now turn to the estimation of the consumer surplus.

5.5.4 Specification of Consumer Surplus

Since the inverse demand function assumes the form,

$$imprice = e^{a0}.anlinc^{a1}.fmemb^{a2}.ptarea^{a3}.discit^{a4}.dis\_ind^{a5}.SO_2^{a6}$$

consumer surplus is calculated by integrating the inverse demand curve with respect to the implicit price and calculating definite (Reimann) integral observed between the old and new levels of SO_2, planned by the policy makers.

Accordingly, the consumer surplus function is specified as :

$$\int imprice = \int e^{a0}.anlinc^{a1}.fmemb^{a2}.ptarea^{a3}.discit^{a4}.dis\_ind^{a5}.SO_2^{a6}$$

$$= e^{a0}.anlinc^{a1}.fmemb^{a2}.ptarea^{a3}.discit^{a4}.dis\_ind^{a5} \int_{so2}^{lowerlim} \mathrm{SO2\ a6}$$

$$= e^{a0}.anlinc^{a1}.fmemb^{a2}.ptarea^{a3}.discit^{a4}.dis\_ind^{a5}.\frac{1}{a_6+1}.\left[\left(lower\lim^{a6+1}\right) - SO_2^{a6=1}\right]$$

Where, *lower*lim is the improvement in environmental quality by a reduction in SO_2 by 10 units.

Hence the consumer surplus is estimated as:

$$CS = e^{13.065}.anlinc^{-2.203E-02}.fmemb^{0.152}.ptarea^{0.785}.discit^{0.303}.dis\_ind^{0.211}.$$
$$\frac{1}{-1.488+1}.\left[\left(lower\lim^{(-1.488+1)}\right)-\left(SO_2^{(-1.488+1)}\right)\right]$$

5.5.5 Estimation of Consumer Surplus

The variations in consumer surplus due to reduced air quality is calculated as the definite integral of the inverse demand function with respect to the air quality between the initial and the final levels. Consider the case where, the level of SO_2 has reduced by 10 percent. The co efficient of SO_2 (- 1.488) could be used to derive consumer surplus for a change in SO_2 and is estimated as follows:

$$CS = e^{13.065}.anlinc^{-2.203E-02}.fmemb^{0.152}.ptarea^{0.785}.discit^{0.303}.dis\_ind^{0.211}.$$
$$\frac{1}{-1.488+1}.\left[\left(lower\lim^{(-1.488+1)}\right)-\left(SO_2^{(-1.488+1)}\right)\right]$$

The Average Consumer Surplus for Cochin, calculated from this equation is given in table 5.13 below:

Table: 5.13
Consumer Surplus per Households

Descriptive statistics	*consumer surplus* (in Rs.)
Mean	53006.49
Standard Error	3039.42
Median	30122.03
Mode	8903.69
Standard Deviation	74450.38
Minimum	3849.64
Maximum	606003.30
Sum	31803896.48
Count	600.00
Confidence Level (95.0%)	5969.22

Source: survey data, 2001-02

The average consumer surplus per person, for Cochin, for a ten percent reduction in SO_2 is Rs.53,006. For 600 individuals the amount of consumer surplus ranges between Rs. 3850 and Rs. 606003.

The value of consumer surplus varies for different individuals at different regions. A ten percent decrease in SO_2 provides different average levels of benefit for different locations. This data is summarised in table 5.14 below.

Table: 5.14
Distribution of Average Consumer Surplus by Locations

Parameter	Eloor	Irumpanam	CSIR	Port trust	Ambalamuga	EKM Nr.
SO_2	122.6	159.6	103.6	66	44.2	98.2
Mean	13307.35	10583.66	18848.28	69388.74	124855.00	81055.93
Standard Error	965.05	796.31	567.65	2259.16	14427.03	3399.24
Median	10144.74	8560.82	19651.63	68046.42	62234.22	83106.61
Mode	33809.72	8903.69	12172.01	40192.09	53912.97	86801.14
Std Deviation	9650.47	7963.13	5676.51	22591.58	144270.29	33992.44
Minimum	3849.64	4150.09	8224.14	34036.55	24563.70	24402.23
Maximum	51058.53	59545.04	37893.60	164544.00	606003.30	162589.30
Sum	1330734.93	1058366.16	1884827.99	6938873.78	12485500.28	8105593.33
Count	100.00	100.00	100.00	100.00	100.00	100.00

Source: Survey data 2001-02.

This table brings out very interesting inferences about the consumer's preferences towards reduced air pollution.

- For instance, reduction in SO_2 does not change consumer surplus in highly polluted areas (Elloor, Irumpanam) compared to those living in less polluted areas (Port Trust, Ambalamugal).
- This implies that a 10 percent reduction in SO2 does not add much benefit to the people in the highly polluted areas, where as, a 10 percent reduction is more valued by the people of less polluted areas.
- People in the less polluted area are more conscious about the impact of SO_2 on property values, compared to those in highly polluted areas.

- Moreover, the elasticity[6] of land price with respect to SO_2 is -1.488, which is in elastic, meaning that a change in SO_2 will reduce house price considerably. The Hedonic property value model, thus predicts positive benefits for households residing in Cochin for a reduction in SO_2.

5.6 Summary and Conclusions

The primary objective of this chapter was to establish the relationship between air quality and the residential property values in Cochin industrial agglomeration in Kerala. This relationship is established by estimating the hedonic property value model. In the model specification, we incorporated a number of structural, neighbourhood, environmental and socio economic variables as determinants of the consumer's willingness to pay for reduced air quality. We hypothesised that the major environmental variable SO_2 is inversely related to the residential property values. Similarly, tree coverage, distance from industry, plinth area of the house, number of toilets, rooms, plot area, availability of electricity, water, fencing and passage are positively related to property prices while distance from city and intensity of traffic are negatively related.

---

[6] The elasticity of land price with respect to SO_2 will be estimated from the implicit price function. Elasticity is given by the formula: $\left(\frac{\partial P}{\partial SO_2}\right) \Big/ \left(\frac{P}{SO_2}\right)$

Adopting a two-stage estimation procedure to estimate these relationships, we found that, on an average, an increase in the level of SO_2 reduced property prices in the study area by 0.45 percent. We estimated the marginal implicit price for reducing SO_2 as Rs. 5154. Estimates further revealed that the households are willing to pay an additional amount of 1.48 percent for a reduction in SO_2. The average consumer surplus per person, for a ten percent reduction in SO_2 is Rs.53, 006 and the range is estimated between Rs. 3850 and Rs. 606003. Although the consumer surplus in high polluted areas (Eloor, Irumpanam) is lower than less polluted areas (Port Trust, Ambalamugal), the latter are more conscious of the impacts of SO_2 on their property values. In short, the analysis revealed a positive response of households in Cochin industrial agglomeration between air quality and property prices.

Chapter 6

Summary and Conclusions

The socio-economic impacts of air pollution are subjects of public concern in developing countries. Despite resistances from environmental movements and international compulsions for safe environmental practices for industrialisation, many developing nations are still using 'pollution generating' technologies for the sake of ensuring economic well-being to the large sections of their labouring classes and poor communities. Although some of these countries, as part of liberalization packages, have been adopting 'environment-friendly technologies' during the last couple of decades, sufficient progress has not been achieved so far due to their own structural problems. The existing scenario of Indian industrialisation also raises similar concerns and very few attempts have been so far made to study how pollution externalities influence the process of the country's industrialisation and its drive towards sustainable economic development[1]. The issue of environmental degradation and the need for evolving a self-sustaining industrial sector has been the primary concern in India and the Government has formulated various legal codes and regulatory regimes to control pollution. Although a number of studies have been recently conducted on the impacts of industrial pollution on public health and the economy of India, no such

[1] Karan Sunil Kumar, (2003); Iyengar, (2003), Behera, Bhagirath, (2002); Murty (2000); Dasgupta, P. (2000) Cropper, (1997); Rezeler, J., (1993);Parikh and Parikh (1994); Rezeler, J., (1993).

serious studies exist in the state of Kerala. This neglect arises from the general feeling with in the bureaucracy that the State does not experience serious contradictions in the use and allocation of its environmental resources for industrialisation. The neglect of environmental issues in the early writings of the apostles of the Kerala Model of development has already been exposed by many scholars recently[2].

Our study is a humble attempt to examine the economic impacts of air pollution on the human health and property values in the industrial capital of Kerala. We observed that the process of industrialisation in Kerala and the increase in air pollution created damages to human, natural and economic resources in the State. The manner in which civil society and the affected households in particular, reacted to their welfare loss varied significantly across different regions and various groups of people and an understanding of such human responses are essential for evolving an environment-friendly approach towards industrialisation. This study was organised to understand this behaviour and to estimate and present information on welfare losses of households affected by air pollution in Cochin industrial agglomeration.

---

[2] The so-called 'Kerala model of development' has become part of the broad global debate about development in the 'third world'. Alexander (1994) has gone so far as to recommend Kerala as a sustainable and eco-friendly model for the whole world in the twenty-first century (Tharamangalam). Franke, (1995) has also raised serious concerns about the environmental degradation as a major problem in Kerala. See footnote number 7 in chapter 1.

The study began by documenting the extent of air pollution and applied econometric approaches to estimate economic impacts of air pollution on human health and property values. Welfare losses for the local households due to air pollution were estimated using Observed Behavioural and Hypothetical Market Survey Methods. 'Marshallian Consumer Surplus' measures were also estimated for obtaining welfare loses in property values due to air pollution. The methods detailed in the introductory chapter, presented the economic models and estimation procedures adopted in this study.

The thesis is organized into six chapters. After introducing the study and the methodology in chapter 1, an attempt was made to review the relevant literature on the impact of air pollution on human health and property values in the second chapter. In the third chapter we outlined the status of air pollution in the Cochin industrial agglomeration. The fourth chapter provided an analysis of the influence of air pollution on human health and chapter five focussed on a detailed analysis of the impact of air pollution on property values.

The brief review of studies undertaken by social scientists in different parts of the world was presented in **chapter two**. The survey helped to examine the complex relationship between air pollution, public health and property values both in the developed and developing nations and enabled us to understand the major theoretical and conceptual issues raised especially by environmental economists in studying such relationships. These surveys revealed clearly that air pollution affected public health and the prices of their property both in the developed and developing nations alike. The recent attempts by scholars to study the environmental issues related to industrialisation has helped to formulate sound economic policies for good environmental governance.

The **third chapter** presented the air pollution scenario of Kerala and provided some scientific evidences on health- air pollution relationship. Air pollution is a serious problem in the industrial capital of the state due to the heavy concentration of air polluting industries and their inability to install sufficient pollution abatement mechanisms. The city of Cochin has witnessed the remarkable deterioration in the quality of air due to early localisation of a variety of air polluting industries and the growth of vehicular traffic. The available data revealed that air pollution exceeded the tolerance limits in many locations near the industrial agglomeration. The results established that, contrary to the general belief, air pollution did matter in the state of Kerala, especially in areas where industries are concentrated.

The immediate target group affected by the high incidence of air pollution has been the local human population. As argued in various chapters of this thesis, both their health and property were directly ruined due to this externality produced by the industries.

Chapter four therefore focussed on estimating their loss in welfare due to air pollution using established methods in environmental economics.

The prime indicator of reduced health status of individual households was defined as Restrictive Activity Days, RAD. Estimation of the regression coefficient of pollution on restrictive activity days, (RAD), using the 'Household Production Function' approach, indicated that restrictive activity days' coefficient in moderate polluted areas- Irumpanam and Ernakulam North- was 12 percent higher than the least polluted areas- Port Trust and CSIR Complex- while restrictive activity days' coefficient in highly polluted areas (Eloor and Ambalamugal) was 18 percent higher than the least polluted areas. This established clearly that the welfare losses due to air pollution were a very serious problem in the study areas.

Accordingly, we estimated the willingness to pay of the affected households using the household's production function and found that the mean willingness to pay, WTP, for high polluted stations- Eloor and Ambalamugal- were Rs.4414 and Rs.6274 respectively. For moderate polluted stations-Irumpanam and Ernakulam North- the mean values were Rs.2997 and Rs.3617 respectively. The regression results also indicated that, when there was a change in air quality, people in moderate polluted areas were willing to pay Rs.3204 more than those in low polluted areas where as in highly polluted areas, people were even willing to pay Rs.4946 more than those in low polluted areas. All variables (disease dummies for asthma, bronchitis, eye irritation, recurrent fever etc., education, smoking, and insurance) other than mitigating cost, monthly income and pollution dummies, showed a negative relationship.

Estimates of willingness to pay, WTP, based on hypothetical markets were also calculated using Contingent Valuation Method (CVM). This method involved asking people whether they would be willing to pay to reduce symptoms corresponding to a change in pollution. Results showed that for highly polluted areas (Eloor and Ambalamugal) the mean willingness to pay values were Rs.932 and Rs.1059 respectively. For moderate polluted areas (Irumpanam and Ernakulam North) mean WTP values were Rs.552.50 and Rs.636 respectively. For less polluted areas (CSIR Complex and Port Trust) the respective mean willingness to pay values were Rs.359 and Rs.481. The different willingness to pay values estimated by Contingent Valuation Method (CVM) method were then regressed with socio economic variables to find their influence on willingness to pay. The estimate indicated that monthly income, mitigating cost, pollution dummies and education dummy have positive and significant impact on willingness to pay. Income is highly significant and is positively related to the willingness to pay of the people, that is, unit increase in income increases willingness to pay by 0.10 units. Mitigating cost also had a positive impact on willingness to pay and was significant. In general, the two approaches provided evidence that, households in the Cochin Industrial Agglomeration value health reduction due to change in air quality. Comparing the estimates of willingness to pay measures we noted a consistent upward bias in the bids obtained using Household Production Function approach than Contingent Valuation Approach. Hence both approaches provided evidence that households were willing to pay for health reduction due to change in air quality. There are two sets of evidence. First, the mean willingness to pay for high and moderate polluted areas were different as per the changes in the level of pollution. The second set of evidence comes from the estimated household production function model, where doctor visits and restricted activity days had significant positive coefficient on two pollution dummies. In both approaches, income is the major factor, which influenced willingness to pay.

The primary objective of **chapter five** was to establish the relationship between air quality and the residential property values in Cochin industrial agglomeration. This relationship was established by estimating the Hedonic Property Value model. Incorporating a number of structural, neighbourhood, environmental and socio economic variables as the determinants of the consumer's willingness to pay for reduced air quality, we hypothesised that the major environmental variable SO2 was inversely related to the residential property values.

Adopting a two-stage estimation procedure to estimate these relationships, we found that, on an average, an increase in the level of SO_2 reduced the property prices in the study area by 0.45 percent. We estimated the marginal implicit price for reducing SO_2 as Rs. 5154. Estimates further revealed that the households are willing to pay an additional amount of 1.48 percent for a reduction in SO_2.

The average consumer surplus per person, for a ten percent reduction in SO_2 is Rs.53, 006 and the range is estimated from Rs. 3850 to Rs. 606003. Although the consumer surplus in high polluted areas (Elloor, Irumpanam) is lower than less polluted areas (Port Trust, Ambalamugal), the latter are more conscious about the impacts of SO_2 on their property values. In short, the analysis revealed a positive response of households in Cochin industrial agglomeration towards reduced air quality. The study also revealed that tree coverage, distance from industry, plinth area of the house, number of toilets, rooms, plot area, availability of electricity, water, fencing and passage were found to be positively related to property prices while distance from city and intensity of traffic are negatively related.

This study therefore, provided very clear evidence to establish the fact that air pollution created damages to human health and their residential property values in Cochin. The trade offs between pollution-health risks and pollution- residential property value damages raised in this thesis challenge the traditional wisdom produced in the Kerala model of development that maintained an academic silence on the environmental concerns of the economy's industrialisation processes.[3]

It also provided the necessary theoretical and empirical support for initiating such modes of governance in Kerala. For instance, it provided useful tips on the welfare losses to various stakeholders rooted on strong environmental economic foundations. Similarly the estimates of willingness to pay measures are helpful in designing various fiscal regimes for environmental governance[4]. This case study is a modest attempt to indicate that policies need to be based on the material realities of the local areas.

In fact, the study provided enough bases for evolving a new development strategy of sustainable industrialisation by considering the environmental needs of the local population, especially to their health and property. In other words, the new Kerala

---

[3] It is interesting to note that similar concerns had already been raised as the limitations of the Model. For instance, the inability of the model to discuss the socio economic and ecological concerns of marginalised communities like the fisher sand tribal communities, is well known (Kurien, 1992) .Similar concerns had also been raised by various social movements and political parties in recent days. Environmental problem such as industrial or automobile air pollution has not accounted serious concern in the development thinking of Kerala People. Also environmental policies haven't made any serious negative or positive influence in the industrial growth of the state. Few environmental problems reported in and after 1980's were related to deforestation, paddy conservation and disruption of backwater ecosystem.

[4] It is unfortunate to note that environmental policy making processes in developing countries had been influenced by western models and the experiences of industries in developed countries. Lack of enough case studies to the satisfaction of drawing meaningful guidelines and generalisations are pointed out as the major reasons for this policy mistake.

Model of development should necessarily incorporate its own environment as an important variable in the development discourse.[5]

This is not to diminish or to negate the ongoing responses of various stakeholders[6] towards air pollution and government's[7] initiatives to regulate its negative impacts. As observed by Rene Veron (2000; 2001) local environmental actions in the state have been emerged mainly due to the conflicts in the regional use of natural resources like water, sand, fisheries, forests etc. and the responses to this environmental degradation came from various quarters. Many industries are facing severe public resistance against the negative impacts of industrialization. At the same time, pollution emitting firms face severe bottlenecks for undertaking abatement measures, especially due to a recent economic crisis evolved due to liberalisation. Government regulatory mechanisms are either not enforced or become ineffective even when enforced.

---

[5] The production trajectories needed to be redefined by introducing pollution as an explicit input variable vector. Increasing number of people's agitations against polluting factories indicate the need for sound pollution management methods in Kerala. Also pollution management should be localized by introducing the concept of participatory planning which comprises decentralized administration, participatory planning and the collaboration between the state, NGOs and civic movements.

[6] Various local level institutions and NGOs such as Kerala Peoples Science Movement (Kerala Shastra Sahitya Parishat KSSP) have raised voice for serious environmental issues. People's struggles against the polluting industries, which directly affect their livelihood in Karimuagal and Eloor of Cochin attracted national and international importance. These two strikes along with some other regional agitations have created a new environmental consciousness in the development model of Kerala.

[7] Under the Indian federal system environmental management is generally organised by various government departments based on formal legal norms and policies crafted by the Central and State governments from time to time Kerala State Pollution Control Board is the official authority to monitor

This indicates towards the limitations of the modes of environmental governance adopted by the centralised bureaucracies for managing air pollution. We shall briefly mention these limitations in the light of this study. For instance, even if good estimates of welfare losses and corresponding willingness to pay measures were available, the governing agency would still require a variety of additional information on the behaviour of other stakeholders including the industry and civil society towards the production and consumption of air pollution. Second, there is the question of choice of an appropriate agency for governance as there is no guarantee whether the industry or the affected stakeholders cooperate in the process of management if measures are designed and enforced unilaterally by the state bureaucracy. Although such considerations are important for evolving good environmental management in areas affected by air pollution, economic valuation studies still merit attention as a guide towards good policy making.

---

environmental quality and quality of industrial discharges. It is generally blamed the PCB for failure to curb the pollution problem arising out of the discharge of toxic effluents from factories in the state.

References:

Afsah, Shakeb. *et.al*, (1996), "Controlling Industrial Pollution," World Bank Policy Research Working Paper: 1672, World Bank, Washington D.C.

Agarwal, Anil., (1997), "The Challenge of the Balance – Environmental Economics in India," Center for Science and Environment, New Delhi.

Antony, C.A., (1998), "Environomics – A Financial Estimate of Environmental Pollution Control Abatement Schemes in Eloor Edyar Industrial Belt," Ph.D Thesis, Cochin University of Science and Technology, Kerala, India.

Alexander, William. M., (1994), "Exceptional Kerala: Efficient Use of Resources and Life Quality in a Non-Affluent Society," *GAIA* (*Ecological Perspectives in Science, Humanities and Economics*), (3) no. 4 (Heidelberg: Spectrum Akademischer Verlag GmbH, 1994).

Alberini, Anna., (1995), "Efficiency Vs Bias of Willingness-to-Pay Estimates: Bivariate and Interval- Data Models," *Journal of Environmental Economics and Management* (29), pp: 169-180.

Alberini, Anna., *et.al.* (1997), "Valuing Health Effects of Air Pollution in Developing Countries: The case of Taiwan," Journal *of Environmental Economics and Management (*34), pp: 107-126.

Alberini, Anna., and Alan, Krupnick (1997), "Air Pollution and Acute Respiratory Illness: Evidence from Taiwan and Los Angeles," *American Journal of Agricultural Economics*, (79), No:5, pp: 1620-1624.

Alberini, Anna., and Alan Krupnick. (1998), "Air Quality and Episodes of Acute Respiratory Illness in Taiwan Cities: Evidence form Survey Data," Journal *of Urban Economics* (44), pp: 68-92.

Alberini, Anna., and Alan Krupnick (2000), "Cost of Illness and Willingness to Pay Estimates of the Benefits of Improved Air Quality: Evidence from Taiwan," *Land Economics*, 76 (1), pp: 37-53.

Allen, Marcus. T., Springer, Thomas M., Waller, Neil G., (1995), "Implicit Pricing across Residential Rental Submarkets," *Journal of Real Estate Finance and Economics*, 11(2), pp. 137-51.

Anderson R.J., and Thomas Crocker, (1971), "Air Pollution and Residential Property Values," *Urban Studies*, Vol: 8, pp: 171-180.

Asian Development Bank., (1996), "Economic Evaluation of Environmental Impacts: A Work Book," Parts: I and II., Environment Division, Asian Development Bank, Manila.

Aunan, K., *et.al,* (1998), "Health and Environmental Benefits from Air Pollution Reductions in Hungary," *The Science of the Total Environment*, (212) pp: 245-268.

Ayres., Robert U. and Leslie Ayres, (1998), "Accounting for Resources-1, Economy wide Applications of Mass Balance Principles to Materials and Waste," Edward Elgar Publishing House, New Delhi.

Ayres., Robert U. and Leslie Ayres, (1999), "Accounting for Resources-2, The life Cycle of Meterials," Edward Elgar Publishing House, New Delhi.

Bartic T. J. (1998), "Evaluating the Benefits of Non Marginal Reductions in Pollution using Information on Defensive Expenditures," *Journal of Environmental Economics and Management* (15), pp: 111-127.

Behera, Bhagirath., and V. Ratna Reddy, (2002), "Environment and Accountability- Impact of Industrial Pollution on Rural Communities," *Economic and Political Weekly*, Jan 19, 2002, pp: 257-265.

Beger Mark. C. *et al.* (1987), "Valuing Changes in Health Risks: A Comparison of Alternative Measures," *Southern Economic Journal*, Vol. 53 (4), pp: 967-84.

Bhattacharya, Rabindra, N, (2001), "Environmental Economics: An Indian Perspective," Oxford University Press, New Delhi.

Bicknell, Kathryn, (2001), "WTP for the Benefits of Environmental Improvement A Literature Review and Some Recommendations," Report No U01/89, Environment, Canterbury, Christchurch.

Bishop and Heberleine, (1979), "Measuring Values of Extra Market Goods: Are Indirect measures biased?" *American Journal of Agriculture Economics* 61, (5) pp: 926-30.

Bishop, Richard *et.al*, "Contingent Valuation" in Daniel Bromley (1995), "The Hand Book of Environmental Economics," Blackwell, USA.

Bishop, Richard., and Donato Romano, (1998), "Environmental Resource Valuation: Applications of the Contingent Valuation Method in Italy," Kluwer Academic Publishers, Boston.

Biswas, D.K., G.K. Pandey, (2002), "Strategy and Policy adopted in Air Quality Management in India," Paper Presented in Better Air Quality in Asian and Pacific Rim Cities, 16 Dec 2002 – 18 Dec 2002, Hong Kong.

Blomquist, Glenn (1979), "Value of Life Savings: Implications of Consumer Activity," *Journal of Political Economy*, (87) pp: 540-558.

Blomquist, Glenn (1981), "The Value of Human Life: An Empirical Perspective," *Economic Enquiry* Vol. XIX, pp: 157-164.

Boyle., et al., (1986), "Starting Point Bias in Contingent Valuation Surveys", *Land Economics*, 61, pp: 188-94.

Braden, B. John., and Charles, D. Kolstad (1992), "Measuring Demand for Environmental Quality" Elsevier Science Publishers, The Netherlands.

Brookshire, D, R., D'Arge, W. Schulze and M. Thayer, (1981), "Experiments in Valuing publics goods," in V.K Smith (ed) Advances in Applied Macro Economics, Vol. (1) Greenwich; CT.

Brookshire, D.S., M.A. Thayer, Schulze, W.D., and R. D'Arge (1982), Valuing public goods: A Comparison of Survey and Hedonic Approaches, *American Economic Review*. (72) 1 pp: 165-177.

Bromley, Daniel (1995), "Hand Book of Environmental Economics," Blackwell, Oxford, U.S.

Brown, Thomas. C., and Robin Gregory (1999), "Why the WTA-WTP Disparity Matters?" *Ecological Economics*, (28), pp: 323-335.

Burtraw, Dallas., and Michael Toman (1997), "The Benefits of Reduced Air Pollutants in the U.S. from Greenhouse Gas Mitigation Policies" Discussion Paper 98-01- Resource for the Future, Washington D.C.

Carson, Richard, T., and Robert Cameron Mitchell (1989), "Using Surveys to Value Public Goods," Resource for Future, Washington D.C.

Central Pollution Control Board (1989-2000), "Ambient Air Quality Monitoring Data Series," Central Pollution control Board, New Delhi.

Central Pollution Control Board (2000), "Air Quality Standards in India," Central Pollution Control Board and Ministry of Environment and Forests, Government of India.

Centre for Science and Environment, (1982), "The State of India's Environment: 1982," Centre for Science and Environment, New Delhi.

Centre for Science and Environment (1985), "The State of India's Environment: 1985-85, The Second Citizen's Report" Centre for Science and Environment, New Delhi.

Chattopadhyay, S. (1999), "Estimating the demand for air quality: New evidence based on the Chicago housing market," *Land Economics*, 75 (1), pp: 22-38.

Chatterji, Manas *et.al* (1998), "Environment and Health in developing Countries" APH Publishing Corporation, New Delhi.

Cheshire, Paul., Sheppard, Stephen (1998), "Estimating the Demand for Housing, Land, and Neighbourhood Characteristics," *Oxford Bulletin of Economics and Statistics*; 60(3), pp: 357-82.

Chestnut, L.G., Ostro, B.D. and N. Vichit-Vadakan, (1997), "Transferability of Air Pollution Control Health Benefits Estimates from the United States to Developing Countries: Evidence from the Bangkok". *American Journal of Agricultural Economics*; (79), 1630-35.

Ciriacy-Wantrup, S.V. (1947), "Capital Returns from Soil-Conservation Practices." quoted in "Dickie M. and Gerking S. (2002) "Valuing Reduced Morbidity": presented at the workshop, "Economic Valuation of Health for Environmental Policy: Assessing Alternative Approaches," March 18-19, 2002, in Orlando, Florida.

Costanza, Robert, *et.al* (1997), "An Introduction to Ecological Economics" ISEE and St. Lucie Press, Boca Raton, Florida.

Creel, Michael (1998), "A note on Consistent Estimation of Mean WTP Using a Misspecified Logit Contingent Valuation Model" *Journal of Environmental Economics and Management*, 35, pp: 277-284.

Crocker, Thomas (1970), "Urban Air Pollution Damage Functions: Theory and Measurement". Riverside, University of California.

Cropper, M. L. (1981), "Measuring Benefits from Reduced Morbidity". *American Economic Review*, (71), no: 2, pp- 235-240.

Cropper, M., and Freeman, M. (1991), "Environmental Health Effects" in "Measuring the Demand for Environmental Quality", (ed) Braden and Kolstad, Elsevier science Publishers, Holland

Cropper., and Oates (1992), "Environmental Economics: A Survey". *Journal of Environmental Economics and Management*, 30, pp: 675-740

Cropper M., Simon., Alberini., Arora Seema and Sharma P.K (1997), "The Health Benefits of Air Pollution Control in Delhi". *American Journal of Agricultural Economics*, (79), No:5, pp: 1625-1629

Cropper, M.L., L.B Deck and K.E McConnell (1988), "On the choice of functional form for hedonic price functions", *Review of economics and Statistics* (70) 4. pp: 668-675.

Cropper M.L., and W.E Oates (1992), "Environmental Economics: a survey" Journal Environmental Economics and Management, 30, pp: 675-740

Culyer, A.J (1991), "Economics of Health" Edward Elgar.

David Austin, et.al (1998), "The Benefits of Air Pollutant Emissions Reductions in Maryland: Results from the Maryland Externalities Screening and Valuation Model" Discussion Paper 99-05, Resources for the Future. Washington D.C.

Davis, R.K. (1963), "The Value of Outdoor Recreation: An Economic Study of the Maine Woods" quoted in "Dickie M. and Gerking S. (2002) "Valuing Reduced Morbidity": presented at the workshop, "Economic Valuation of Health for Environmental Policy: Assessing Alternative Approaches," March 18-19, 2002, in Orlando, Florida.

Dasgupta, P. (2001), "Valuing Health Damages from Water Pollution in Urban Delhi, India: A Health production Function Approach", Working Paper Series: No: E/210/2001. IEG, New Delhi.

Desvous, W.H, V.K. Smith and H.H Rink III (1989), "Communicating radon risk effectively: radon testing in Maryland" USEPA, Office of Policy, Planning and Evaluation, Washington.

Dickie M., and Gerking S. (1989), Valuing Non market Goods: A household Production Approach". Paper Presented in the Association of Environmental and Resource Economist's Conference on estimating and Valuing Morbidity in a Public Context, June 8-9 1989, research Triangle Park, N.C.

Dickie M., and Gerking S. (1991a), "Valuing Reduced Morbidity: A household Production Approach". *Southern Economic Journal,* Vol.57, No: 3, pp: 690-702

Dickie M.,and Gerking S. (1991b), "Willingness to Pay for Ozone Control: Inference from the demand for Medical Care". *Journal of Environmental Economics and Management* (21) , pp: 1-16.

Dickie., M. and Ulery V.L. (2001), "Valuing Health in the Household: Are Kids Worth More than Parents?" Presented at the Association of Environmental and Resource Economists workshop, "Assessing and Managing Environmental and Public Health Risks," Bar Harbor, Maine, June 13-15

Dickie M., and Gerking S (2002), "Willingness to Pay for Reduced Morbidity". Paper presented at the workshop, "Economic Valuation of Health for Environmental Policy: Assessing Alternative Approaches," March 18-19, 2002, in Orlando, Florida

Dietrich, Earnhart (2001), "Combining Revealed and Stated Preference Methods to Value Environmental Amenities at Residential Locations" *Land Economics*, February. 77 (1): pp: 12-29.

Dixon, A. John *et.al* (1995) "Economic Analysis of Environmental Impacts." Earth Scan Publishers.

Dorfman, Robert., and Nancy, S. Dorfman. (1972), "Economics of the Environment – Selected Readings" W.W. Norton and Company.Inc. New York.

Epple, D. (1984), "Closed form solutions to a class hedonic equilibrium models" Working paper, Carnegie- Mellon University, Pittsburg.

Epple, D. (1987), "Hedonic Prices and implicit markets: estimating demand and supply functions for differentiated products" Journal of Political Economy (95) pp: 59-80

Farber, S., and A. Rambaldi. (1993), "Willingness to Pay for Air Quality: The Case of Outdoor Exercise." *Contemporary Policy Analysis* XI (October 1993), pp 19-30.

Figueroa B., Eugenio., Rogat C., Jorge., Firinguetti L., Luis, (1996), "An Estimation of the Economic Value of an Air Quality Improvement Program in Santiago de Chile," *Estudios de Economia*; 23(0), Special Issue 1996, 99-114.

Fisher, A.C., and F.M, Peterson., (1976), "The Environment in Economics: A Survey" *The Journal of economic Literature*, 19, (1), pp. 1-33

Fullerton, Don (2001), "A Framework to Compare Environmental Policies" *Southern Economic Journal*, 2001, 68 (2), pp: 224-248.

Franke, Richard W. (1995), "Is There a Kerala Model?" Paper Presented at the World Malayalee Convention '95, July 1-3, Garden State Exhibit Center, Somerset, New Jersey.

Freeman A.M (1974), "Air Pollution and Property Values: a further comment" *Review of Economics and Statistics* (56) pp: 554-556.

Freeman III, M. (1979a), "The Benefits of Environmental Improvemet: Theory and Practice". Resources for the Future, Washington D.C

Freeman III, M. (1979b), "Hedonic prices, property values and measuring environmental benefits, a survey of the issues", *Scandinavian Journal of Economics*, (81), pp: 155-173.

Freeman III Myrick, M. (1993), "The Measurement of Environmental and Resource Values; Theory and Methods". Page: 315, Resources for the Future, Washington D.C

Garrod .G., and Kenneth, G. Willis (1992), "The amenity value of woodland in Great Britain", *Environmental and Resource Economics* 2, (4), pp: 415-434

Garrod .G., and Kenneth, G. Willis (1998), "Economic Valuation of the Environment- Methods and Case Studies" Edward Elgar Publishing House, Newdelhi.

Gayer, T., J. T. Hamilton, and W. K. Viscusi (2000), "Private values of risk tradeoffs at superfund sites: Housing market evidence on learning about risk," *Review of Economics and Statistics*, 82 (3), pp: 439-451.

Gerking, S., and L.R Stanley (1986). "An Economic Analysis of Air Pollution and Health: The case of St. Luise" *Review of Economics and Statistics*, (68), pp: 115-121.

Giannias D.A (1988), "A Structural approach to hedonic equilibrium models" Working paper, University of Guelph, Ontario

Godleski, John J, et.al (2000), "Mechanisms of Morbidity and Mortality from Exposure to Ambient Air Particles" Resesrch Report, Health Effects Institute, Cambridge.

Goodwin, Susan A (1977),"Measuring the Value of Housing Quality- A Note" *Journal of Regional Science*, Vol: 17 (1) pp: 107-115.

Government of India, (2002), "Economic Survey" Ministry of Finance and Company Affairs.

Government of Kerala (2002), "Economic Review" State Planning Board, Tivandrum, Kerala.

Graves, P.E., J.C Murdoch., M.A Thayer and D. Waldman (1988), "the robustness of hedonic price estimation: urban air quality" *Land Economics*, (64), pp: 220-223

Greenpeace, (1999), "Toxic Hotspots: A Greenpeace Investigation of Hindustan Insecticides Ltd Udyogmandal Industrial Estate, Kerala" Technical Note 06/99.

Greenpeace, (2003), "Status of Human Health at Eloor Industrial Estate, Kerala", Report Greenpeace India.

Grossman, Michael (1972), "On the concept of Health Capital and the Demand for Health". *Journal of Political economy,* Vol. 80, No: 2, pp- 223-255.

Gupta, Indrani (2000), "Willingness to Avoid Health Costs: Results from a Delhi Survey" Discussion Paper Series No: 15/2000, Institute of Economic Growth, New Delhi.

Haab, C. Thimothy (1998), "Estimation Using Contingent Valuation Data from a 'Dichotomous Choice with Follow Up' Questionnaire: A Comment" *Journal of Environmental Economics and Management* (35), pp: 190-194.

Hadden, G. Susan (1987), "Status and Standards of Pollution Control in India" *Economic and Political Weekly*, Vol: XXII, No: 16.

Halvorsen and Pollakowski (1988), "Choice of functional form of hedonic price Equations" *Journal of Urban Economics* (10) pp: 37-49

Hanley, Nick., Shogren and Ben White (1997), "Environmental Economics: In Theory and Practice" Mac Million India, New Delhi.

Harrington, Wintson and Paul. R. Portney (1987), "Valuing the Benefits of health and Safety Regulations". *Journal of Urban Economics*, Vol.22, No.1, pp-102-112

Harrison D and D.L Rubinfield (1978), "Hedonic housing prices and the demand for clean air" *Journal of Environmental Economics and Management* (5) pp: 81-102

Harrison, David, Jr. Stock, James H. (1986), "Hedonic Housing Values, Local Public Goods, and the Benefits of Hazardous Waste Cleanup," Harvard Energy & Environmental Policy Center Discussion Paper Series: E-84-09.

Hettige, Hemamala., Muthukumara Mani., and Devid Wheeler (1997), "Industrial Pollution in Economic Development: Kuznet's Curve Revisited" Development Research Group, World Bank.

Huh, Serim., Kwak, Seung Jun, (1997), "The Choice of Functional Form and Variables in the Hedonic Price Model in Seoul," *Urban Studies*; 34(7) pp: 989-98

IGIDR (2000), "Clean AIR", Environmental Governance-4', IGIDR, Mumbai.

Iyengar (2003), "Environmental Damage to Land Resource: Need to Improve Land Use Data Base" *Economic and Political Weekly*, August, 23, 2003. pp: 3596-3604

James Brown and Harvey Rosen, (1982), "On the estimation of structural hedonic price models," *Econometrica* Vol. 80 (3) pp: 765-768.

Karan, Sunil Kumar., Shigeo Shikura., Hideki Harada (2003), "Living Environment and Health of Urban Poor: A Study in Mumbai" *Economic and Political Weekly*, August, 23, 2003. pp: 3575-3586.

Kerala State Pollution Control Board (1997), "Environment, Effluent, Emmission and Noise Standars and Guidelines" State PCB, Trivandrum, Kerala.

Kohn, Robert, E. (1998), "Pollution and the Firm" Edward Elgar, New Delhi.

Kolstad, Charlse, D., and Rolando M. Guzman. (1999), "Information and divergence Between Willingness to Accept and Willingness to Pay" *Journal of Environmental Economics and Management*, (38) pp: 66-80.

Kolstad, Charlse, D. (2000), "Environmental Economics" Oxford University Press.

Konisky, David M. (1999), "Comparative Risk Projects: A Methodology for Cross-Project Analysis of Human Health Risk Rankings" Discussion Paper 99-46, Resources for the Future. Washington D.C.

Korakandy, Ramakrishnan (2000), "State of Environment in Kerala: What Price the Development Model?" *Economic and Political Weekly*, May 27- June 2, 2000. www.epw.org.in.

Kuchler, Fred., and Golan Elise., (1999), "Assigning Values to Life: Comparing Methods for Valuing Health Risks". Agricultural Economic Report Number 784, US Department of Agriculture, Washington D.C.

Kuik, O.J, *et.al* (1997), "Pollution control in the South and North- A Comparative Assesment of Environmental Policy Approaches in India and the Netherlands." Sage Publications, new Delhi.

Kurian, John (1992), "Ruining the Commons and Responses of the Commoners: Coastal Over fishing and Fish workers' Actions in Kerala State, India", in Ghai, D. and J.M. Vivian (eds.)

Krupnick, A., K. Harrison., Eric Nickell, and M. A.Toman (1996), "The Value of Health benefits from Ambient Air Quality Improvements in Central and Eastern Europe: an Exercise in Benefit Transfer" *Environmental and Resource Economics*, Vol. 7, pp: 307-332.

Krupnick,Alan et.al (2000), "Age, Health, and the Willingness to Pay for Mortality Risk Reductions: A Contingent Valuation Survey of Ontario Residents." Resources for the Future. Washington D.C

Lang, C. (1995), "Environmental and Health Benefits of Cleaner Vehicles and Fuels", prepared for the Canadian Council of Ministers of the Environment Task Force on Cleaner Vehicles and Fuels.

Langford H. Ian *et.al* (1998), "Improved Estimation of Willingness to Pay in Dichotomous Contingent Valuation Studies" *Land Economics*, (74) 1 pp: 65-75.

Larson, Bruce A., et al., (1999), "The Economics of Air Pollution Health Risks in Russia: A case study of Volgograd", *World Development*, (10), pp: 1803-1819.

Lauraine G., Ostro D and Vadakan, Vichit (1997), "Transferability of Air Pollution Control Health Benefits from the United States to developing Countries: Evidence from the Bangkok Study" *American Journal of Agricultural Economics*, (79), No:5, pp: 1630-1635

Levesque, Terrence J., (1994), "Modelling the Effects of Airport Noise on Residential Housing Markets: A Case Study of Winnipeg International Airport," *Journal of Transport Economics and Policy*, 28(2), pp. 199-210.

Linnerooth, Joanne (1979) "The Value of Human Life: A Review of the Models" *Economic Enquiry*, Vol. XVII, pp: 52-74.

Loehman, et.al (1979), "Distributional Analysis of Regional Benefits and Cost of Air Quality Control." *Journal of Environmental Economics and Management*, Vol.6, pp 222-243.

Loehman, Edna T., Park, S. and Boldt, D. (1994), "Willingness to Pay for Gains and Losses in Visibility and Health." *Land Economics*. 70(4): pp: 478-98.

Mahan, B. L., S. Polasky, and R. M. Adams (2000), "Valuing urban wetlands: A property price approach,"*Land Economics*, 76 (1), 100-113.

Mailer, Kral Goran (1977), "A Note on the use of Property Values in Estimating Marginal willingness to Pay for Environmental Quality" *Journal of Environmental Economics and Management*, (4); pp: 355-369.

Markandya, A., and Julie Richardson (1997), "Earth Scan Reader in Environmental Economics" Earth Can Publishers, London.

Markandya, A and M.N. Murty (2000), "Cleaning-Up the Ganges" Oxford University Press.

Mason, Carl., Quigley, John M, (1989), "Explicit Models of Willingness to Pay: A Monte Carlo Simulation," University of California at Berkeley Working Paper in Economics: pp: 89-109

Mazurek, Janice V. (1996), "The Role of Health Risk Assessment and Cost-Benefit Analysis in Environmental Decision Making in Selected Countries: An Initial Survey" Discussion Paper 96-36, Resources for the Future. Washington D.C.

McConnell, K.E., and T. T Phipps (1987), "Identification of Preference Parameters in Hedonic models: Consumer Demands with Nonlinear Budgets" *Journal of Urban Economics* (22) pp: 35-52

McDougall, S. Gerald., and Colin Wright (1980), "A Proposal for Improving the Measurement of Benefits form Pollution Abatement" *Journal of Environmental Economics and Management,* (7), pp: 20-29.

Mendelsohn (1984), "Estimating structural equations of implicit markets and household production functions" *Review of Economics and Statistics*, 66 (4) pp: 673-77

Mendelsohn, (1985), "Identifying structural equations with single market data" *Review of Economics and Statistics* (67) pp: 525-529

Michael, H. J., K. J. Boyle, and R. Bouchard (2000), "Does the measurement of environmental quality affect implicit prices estimated from hedonic models?," *Land Economics*, 76 (2), pp: 283- 298.

Mitchell, R. and Carson R.T. (1989), Using Surveys to Value Public Goods: The Contingent Valuation Method. Washington, DC: Resources for the Future.

Moon, Wanki *et.al* (2002), "Willingness to Pay for Environmental Practices: Implications for Eco-Labeling" *Land Economics*, 78 (1), pp; 88-102.

Murty, M.N (2000), "Environmental Regulations and Economics of Developmental Policies" Working Paper, Institute of Economic Growth, New Delhi.

Murty M.N., and A .Markandya. (2000), "Cleaning Up the Ganges – A Cost benefit Analysis of the Ganga Action Plan" Oxford University Press.

Murty M. N., and Surender Kumar (2000), "Measuring Cost of Environmentally Sustainable Industrial Development in India: A distance Function Approach" Working Paper Series No: E/208/2000. Institute of Economic Growth, Delhi.

Murty, M. N., and Surender Kumar (2001), "Methodology for estimating the cost of Pollution Abatement: A Review of Literature" Working Paper Series No: E/217/2001. Institute of Economic Growth, Delhi.

Murty, M. N. and Surender Kumar, (2002), Chapter 5, "Environmental and Economic Accounting for Industry", Oxford University Press, New Delhi.

Murdoch J.C., and M.A Thayer (1988), "Hedonic Price Estimation of Variable urban air quality" *Journal of Environmental Economics and Management* (15) pp: 143-146.

Navrud, Stale (1998), "Valuing health Impacts from Air Pollution in Europe: New Empirical evidence on Morbidity" Paper presented for the World Congress for Environmental and Resource Economists, June 25-27, Venice, Italy.

Nellison, Nico *et.al* [ed.] (2001), "Classics in Environmental Studies" Kusum Publishing, New delhi.

Nelson J.P (1978), "Residential Choice, Hedonic Prices and the Demand for Urban Air Quality" *Journal of Urban Economics*, 5; pp: 357-369.

Nelson J.P (1980), "Airports and Property values : a survey of recent evidence" *Journal of Transport Economics and Policy* (14), pp: 37-52

Ohlsfeld (1985), "Assuming accuracy of structural perameter estimates in analysis of implicit market prices." *Land Economics*, 64 (2) pp: 135-146

Ostro, B. (1983), "The Effects of Air Pollution on Work Loss and Morbidity" *Journal of Environmental Economics and Management* (10), pp: 371-382.

Ostro, B. (1987), "Air Pollution and Morbidity Revisited: A Specification Test " *Journal of environmental Economics and Management* (14), pp: 87-98.

Ostro, B. (1994), "Estimating Health Effects of Air Pollutants – A method with an Application to Jakarta" World Bank Policy Research working Paper: 1301, World Bank, Publication Division.

Ostro, B. et.al (1995), "Air Pollution and Mortality- Results from Santiago, Chile" World Bank Policy Research working Paper: 1453, World Bank, Publication Division.

Palmquist (1982), " The Effects of Air Pollution on Residential Property Values" Working Paper, North Carolina State University, Raleigh, NC.

Palmquist (1983), "Estimating the Demand for Property value Studies" Working Paper, North Carolina State University, Raleigh, NC.

Palmquist (1984), "Estimating demand for the characteristics of the Housing" *Review of Economics and Statistics* 66 (3) pp: 394-404

Palmquist, Raymond B., Roka, Fritz M., Vukina, Tomislav, (1997), "Hog Operations, Environmental Effects, and Residential Property Values," *Land Economics*; 73(1), February 1997, 114-24.

Palmquist, Raymond. B (1988), "Welfare measurement for Environmental Improvements using Hedonic model: The case of nonparametric marginal prices" *Journal of Environmental Economics and Management* (15), pp: 297-312

Palmquist, Raymond B.; Roka, Fritz M.; Vukina, Tomislav, (1997), "Hog Operations, Environmental Effects, and Residential Property Values," *Land Economics*; 73(1), pp: 114-24.

Parayil, Govindan (2000), "Kerala, The Development Experience, Reflections on Sustainability and Replicability" Zed Books.

Pargal, Sheoli., Muthukumara Mani., and Mainul Huq (1997), Inspections and Emissions in India: Puzzling survey Evidenec on industrial Water Pollution" PRD Working Paper, 1810, The World Bank Development Research Group, Washington D.C.

Parikh, S. Kirit., Jyoti K. Parikh., T. R. Muraleedharan and Nandini Hadkar (1994), "Economic Valuation of Air pollution in Chembur, Bombay, India" IGIDR, Mumbai.

Pearce. D., and A. Markandya (1989), "Environmental Policy Benefits" Monitory Valuation, OECD, Paris.

Peckham, Barain (1970), "Air Pollution and Residebtial property Values in Philadelphia". (mimeo) Quoted in Freeman , M. (1979a), "The Benefits of Environmental Improvemet: Theory and Practice". Resources for the Future, Washington D.C

Pedrick, Amy M. (2001), "The Health Production Function: The effect of socio-economic variables on an individual's health status" Project Report, Union College Schenectady, New York.

Perman, Roger., Yu Ma., and James Mc Glivary (1999), "Natural Resource and Environmental Economics." Longman Publishers, England.

Peterson and William (1975), "Population", Mc.Million, New York.

Pigou, A.C (1920), "The Economics of Welfare" Mac Million, London

Polinsky, A Mitchell., and D.L Rubinfeld (1977), "Property Values and the Benefits of Environmental Improvements: Theory and Measurement" in Lowdon Wingo and Alan Evans (ed.) "Public Economics and Quality of Life", Resource for Future and The Center for Environmental Studies.

Poor Joan, P. *et.al* (2001), "Objective Versus Subjective Measures of Water Clarity in Hedonic Property Value Models" *Land Economics*, 77 (4) pp: 482-493.

Ravichandran., M and S. Dhanaraj (1997), "Economic Implications of Industrial Pollution Control" *Productivity*, Vol: 37, (4), 1997.

Rajalaxmi and Dhulasi Birunda (1994), "Environomics, Economic Analysis of Environment" Allied Publishers, India.

Rezeler, J., (1993), "Economic Costs of Environmental Degradation in Bombay Metropolitan Region" presented at the workshop on Economic Valuation of Environmental Degradation, IGIDR, Mumbai

Ridker Ronald (1967), "Economic Costs of Air Pollution: Studies in Measurement" Praeger, New York

Ricker and Henning, (1967), "The Determinants of Residential Property Values with Special reference to Air Pollution" *Review of Economics and Statistics*, Vol. 49, No. 2, pp: 246-257

Rowe et al., (1980), "An Experiment on the Economic Value Visibility". *Journal of Environmental Economics and Management*, 7, pp: 1-19.

Rowe, R.D. and L.G. Chestnut (1985), "Oxidants and Asthmatics in Los Angeles: A Benefits Analysis" Report to the Office of Policy Analysis, US Environmental Protection Agency. Energy and Resource Consultants, Inc.

Ruff .E. Larry (1972), "The Economic Common Sense of Pollution" edited in "Economics of the Environment, Selected Readings", Dorfman and Dorfman (1972), W.W. Norton and Company, NY

Sankar, Ulakanathan (1998), "Laws and Institutions Relating to Environmental protection in India" Paper presented at the Conference on the Role of Law and Legal Institutions in Asian Economic Development, Rotterdam.

Sankar, Ulakanathan (2001), "Environmental Economics" Oxford University Press.

Schanare, Ann B (1976), "Racial and Ethnic Price Differentials in Urban Housing Markets" *Urban Studies*, Vol: 13, pp: 146-166.

Schoenbaum and Rosenberg (1991), "Environmental Policy Law" The foundation Press, NY

Shaman, David (1996), "India's Pollution Regulatory Structure and Back Ground" NIPR, the World Bank Group, http://wb.forumone.com/niprcd/india/india-back.htm.

Small K.A (1975), " Air Pollution and Property Values: a further comment" *Review of Economics and Statistics* (57) pp: 105-107.

Smith, Barton (1978), "Measuring the Value of Urban Amenities" *Journal of Urban Economics*, Vol: 5, pp: 370-387

Smith, V.K and W.H Desvousges (1986), "Measuring Water Quality Benefits" Boston: Kluwer – Nijhoff Publishing House.

Smith, K.R (1988), " Indoor Air Pollution in India: National health Impacts and Cost Effectiveness of Interventiuons" Report Prepared for Capacity 21 Project of India, aided by World Bank.

Smith, K.R., (2000), "National Burden of Disease in India from Indoor Air Pollution". Proceedings of the National Academy of Sciences, USA (PNAS 2000 97: 13286-13293).

Smith, V. Kerry, (1990), "Can We Measure the Economic Value of Environmental Amenities?" *Southern Economic Journal*, 56(4), pp. 856-78

Smith, V. Kerry; Huang, Ju Chin, (1995), "Can Markets Value Air Quality? A Meta-analysis of Hedonic Property Value Models," *Journal of Political Economy*, 103(1), pp. 209-27.

Spitzer J.J (1982), "A Premier on Box-Cox Estimation" *Review of Economics and Statistics*, (64) pp: 307-313.

Spore, Robert (1972), "Property Value Differentials as a Measure of the Economic Costs of Air Pollution" Center for Air Environment Studies, Pennsylvania State University.

Stedman, John. R., Katie King., and Mike Holland., (2001), "Quantification of the Health Effects of Air Pollution in the U.K for PM_{10} Objective Analysis". A report produced for the Department for Environment, Food and Rural Affairs, The National assembly for Wales, Northern Island.

Steele, Willaim (1972), "The Effect of Air Pollution on the Value of Single Family Owner occupied Residential Property in Charlsetown, South Carolina" Masters Thesis, Clemson University.

Swamy, Durai, P, (2000), "Health Status and Curative Health Care in Rural India" Paper written under the program of Research in Human Development, Natioanl council of Applied Economic Research, New Delhi

Taylor, L. O., and V. K. Smith (2000), "Environmental amenities as a source of market power," *Land Economics*, 76 (4), pp: 550-568.

Terance J. Rephann (1998), "Explaining Property Values:Quantitative Evidence from Sweden" Paper presented at the 36 th annual meeting of the North American Regional Science Association in Santa Fe, New Mexico on November 13-16, 1998

Thanh, Bui Duy and Thierry Lefevre. (2000), "Assessing Health Impacts of Air Pollution from Electricity Generation: The Case of Thailand". *Environmental Impact Assessment Review*, (20), pp: 137-158.

Tharamangalam, Joseph, "The Perils of Social Development without Economic Growth: The Development Debacle of Kerala, India". http://csf.colorado.edu/bcas/kerala/kerther1.htm#n4

Thomson, K.T (2002), "Socio- Economic Issues of Biodiversity Degradation in the Cochin Backwaters" Report Submitted to KRPLLD, CDS, Trivandrum.

Thomson, K.T (2003), "Economic and Social Management of Estuarine Biodiversity in the West Coast of India" Report Submitted to IGIDR, Mumbai, World Bank aided 'India: Environmental management Capacity Building Technical Assistance Project.'

Tie:enberg, Tom (2002), "Environmental and Natural Resource Economics" Pearson Addison Wesley.

Tiwari, Piyush; Parikh, Jyoti, (1997), "Demand for Housing in the Bombay Metropolitan Region," *Journal of Policy Modeling* 19(3), pp: 295-321.

Turner, Kerry, David Pearce and Ian Bateman (1994), "Environmental Economics: An Elementary Inroduction" Harvester Wheatsheaf, Newyork.

United Nations (1997), "Environmental Accounting and Valuation: Volume I, A Premier for Developing Coutries" Economic and Social Commission for Asia and Pacific Region, UN, New York.

United Nations (1997), "Environmental Accounting and Valuation: Volume II, A Premier for Developing Coutries" Economic and Social Commission for Asia and Pacific Region, UN, New York.

US Department of Health, Education and Welfare, National Center for Health Statistics. "Health procedure, Vital and Health Statistics programs and Collection Procedures" (1964), Series No.1, No:2

Veron, Rene (2000), 'Sustainability and the "New" Kerala Model.' In The Kerala Model of Development: Reflections on Sustainability and Replicability. Zed Books.

Veron, Rene (2001), "The New Kerala Model: Lessons for Sustainable Development," *World Development* 29, 4, 2001, pp. 601-617.

Weinrobe, Maurice (1973), "Accounting for Pollution: Pollution Abatement and National Product." *Land Economics*, XLIX, (2).

Witter, Sophie, et.al (2000), "Health Economics for Developing Countries: A Practical Guide" Macmillion.

World Bank., (1998), "Pollution Prevention and Abatement Handbook" Part I, II, and III, World Bank group, Washington D.C.

World Bank., (2000), "Greening Industry – New roles for Communities, Markets and Governments". A World Bank Policy Research Report. Oxford University Press.

World Health Organisation., (1985), " Environmental Pollution Control in Relation to Development" WHO Technical Report Series 718, WHO, Geneva.

World Health Organisation., (2001), "Health Impact Assessment of Air Pollution in the Eight Major Italian Cities". WHO Regional Office for Europe.

Wu, Pei-Ing., Chu-Li Huang., (1998), "Actual Averting Expenditure vs. Stated Willingness to Pay" Paper prepared for the presentation at the First World Congress of Environmental and Resource Economists, June 25-27, 1998. Venice, Italy, Isola di San Giorgio.

Xu, Feng, *et.al* (1993), "Measuring the Contributions of Site Characteristics to the Value of Agricultural Land" *Land Economics*, 69 (4), pp: 356-69.

Zabel, J. E., and K. A. Kiel (2000), "Estimating the demand for air quality in four US cities," *Land Economics*, 76 (2), pp: 174-194.

Zerbe, Robert Jr. (1969), "The Economics of Air Pollution: A Cost Benefit Approach" Toronto, Ontario department of Public Health.