Contents

Natural Resource Accounting for
West Bengal for the Sectors: Air and Water

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Chapter I

Introduction

Need for Green Accounting

The concern and awareness of environmental problems has grown over the last 25 years and thus the world has been deluged with reports, action plans and other prescription to cure all environmental ills. The trade off between competing priorities of short-term development and environmental quality harps on the basic fact that sometimes economic benefits are not commensurate with the losses on the environmental fronts.

International conferences, ministerial declaration, government policy documents, political manifestoes, are now deeply committed to a new ethic, the ethic of sustainable development. The concept of sustainable development was introduced by the International Union for the Conservation of Nature and Natural Resources. But the concept was popularized by the Brundtland Commission Report, our common future which states that " Humanity has the ability to make development sustainable – to ensure that it meets the need of the present generation without compromising the ability of the future generations to meet their own needs" (World Commission on Environment and Development, 1987 P8).The Brundtland Commission definition of sustainable development has been kept intentionally vague so that it doesn't remain confined to any particular category of needs.(UN 2003)

Approaches to Green Accounting

However the Brundtlant report offers little in terms of the measurable objectives of sustainable development. To understand the implication of current and future path of development, researchers from various disciplines have tried to operationalize the concept. As a result the diverging viewpoints have emerged (UN 2003) which are

1) The three pillar approach
2) The ecological approach
3) The capital approach

1) The three-pillar approach to sustainable development refers to simultaneous address of economic, social and environmental systems. Each pillar is independently crucial and interconnected. Thus they can never be sequentially addressed but needs to be considered simultaneously.
2) The ecological approach emphasizes the notion that the economic and social systems are sub systems of the global environment. It follows that sustainability in the economic and social spheres is subordinate to sustainability of the environment.
3) The capital approach to sustainable development reinvented the definition of capital by making it broader. In the past, economist tended to focus on produced capital as the only source of wealth and therefore income. Natural resources were then considered to be the free gifts of nature as they were unlimited in supply. However, with the increasing population and the level of economic activity the demand for natural resources increases which may even exceed the stock of natural resources. Thus natural resources can no longer be taken for granted and considered as free gifts of nature. They need to be protected, nourished and preserved for maintaining the productive capacity of the environment for the present as well as future generations. Thus the capital approach to sustainable development emphasized that natural capital cannot be ignored in any discussion of the sustainability of national income and wealth. The productive base of the economy must therefore consider an optimal portfolio mix of manufactured capital, human capital, natural capital and knowledge.

Though there is agreement that all forms of capital are important when considering sustainability but there is divergence of views as to whether the various forms of capital are substitutes or complements or whether the different forms of capital at all share a relationship of substitutability or complementarities and thus led to the emergence of two polar opposite view points- the weak sustainability and the strong sustainability.

Weak sustainability allows depletion of natural capital stock, so long as the depletion is offset by the increase in the stock of other forms of capital and assumes that all forms of capital are substitute of one another. Strong sustainability requires that all forms of natural capital to be maintained independent of one another as it assumes that different form of natural capital are complementary to each other. The proponents of strong sustainability claims that only be maintaining both natural and produced capital stock intact, the property of non-declining income of sustainable development can be maintained.

The concept of weak sustainability can be stated as follows:

If we assume benefit from the investment portfolio as B_t, non- environmental cost as C_t, environmental cost as E_t and δ_t as the discount factor, K_n as the natural capital measured in monetary terms then using cost benefit analysis criterion over the discrete time period t = 1, 2,3,…………T

$$\sum_{t=1}^{T} B_t d_t - \sum_{t=1}^{T} C_t \delta_t - \sum_{t=1}^{T} E_t d_t > 0$$

that is, the sum of the discounted net benefit is positive.

The weak sustainability constraint is that

$$\sum_{t=1}^{T} \sum_{i=1}^{n} E_{it} d_t \leq \sum_{t=1}^{T} \sum_{j=1}^{m} a_{jt} d_t$$

where there are I=1,2,3,……..n projects/policies in the portfolio and j=1,2…….m shadow projects and where a represents the environmental benefits associated with each shadow project a_{jt} .

The strong sustainability constraint is

$$\sum_{i=1}^{n} E_i \leq \sum_{j=1}^{m} a_j \quad \forall \text{ t=1,2,3……….T}$$

Thus, the weak sustainability states that, Discounted sum of environmental cost ≤ Discounted sum of offsetting benefits over the time period in question. Thus weak sustainability substantiates the fact that natural resource stock can de depleted if the depletion is offset by equivalent increase in other forms of capital.

In strong sustainability case however, Environmental costs are no greater than environmental benefits in each time period. Thus strong sustainability proposes maintenance of all form of capital stock independent of one another.

It must be remembered that sustainability is essentially a long run problem, an intergenerational issue and thus future options can never be forgone. Thus, the inherent precautionary clause of strong sustainability needs to be considered and prudent decisions are to be applied while making use of natural resources. But in order to take any decision as to the use and management of natural resources requires understanding of the concept of natural resource or natural capital, the components that are considered as natural capital and accounting the natural capital.

It is not easy to value or measure natural resources. Conceptual difficulties, unavailability of measuring techniques coupled with paucity of adequate data make the matter worse. In spite of all these limitations natural resource accounting is important to keep track of the environmental consequences of economic activities. Such accounting practices may alter our perception of the kind of development that is desirable for our economy and may also change the course of policy actions.

The conventional accounting framework and gaps

The conventional accounting framework, the System of National Accounts (SNA)was developed by United Nations and it has been used by most countries of the world for the computation of the national income, domestic product at an annual basis.

System of National Accounts has been defined as a statistical compendium showing the expenditures and income of the nation on an annual basis (Kadekodi, 2004). It consists of a coherent, consistent and integrated set of macroeconomic accounts balance sheet and tables based on a set of internationally agreed concepts, definitions, classifications and accounting rules. The accounting is entirely done on the commodities which are valued in terms of the market prices. Though the natural resources contribute immensely the generation of income and wealth they are not considered in the conventional accounting framework as they do not command a market price. Natural resources or natural capital are like the man-made capital and the accounting of the resources will be in the line of capital formation i.e. generation of natural capital must be added whereas the degradation must be subtracted to arrive at a net value. But in addition to this, the sustainability principle will always be the guiding principle of natural resource accounting.

Accounting for natural capital : SEEA through satellite systems of accounts

These gaps in the conventional accounting structure to account for the environment prompted the economist world wide to think and rethink as to how to account for the environmental resources or the natural capital?

The concept of resource accounting evolved around 1970s when the energy crisis led to energy measures. The Rio Earth Summit (1993) recognized the importance of environmental assessment and recommended all nations along with United Nations in particular to develop a System of Integrated Environmental and Economic accounting (**SEEA).** Thus the United Nation Statistical Division responded to the need of the situation and came up with the system of Integrated Economic and Economic Accounting. However, the methods and the concepts in this handbook are not the final conclusion and thus the handbook was issued as an interim version of the work in progress. In 2003, the revised handbook was published jointly by United Nations, the International Monetary Fund, the Organization of Economic Cooperation and Development, the Statistical Office of the European Communities (Eurostat) and the World Bank.

The SEEA aimed at integrating environment and social dimensions in the accounting framework at least through **satellite system of accounts**. The satellite system of natural resource account is a modified system of income accounting showing environmental related sectoral activities separately along with their physical account flows changes valuation and possible link to main SNA.

Now, the question arises what is SEEA or what are the components of SEEA? The System for integrated Environmental and Economic Accounting is a satellite system of the SNA that comprises 4 categories of accounts.

Hybrid flow account

The first considers purely physical data relating to flows of materials and energy and marshals them as far as possible according to the **accounting structure of the SNA**. The accounts in this category also show how flow data in physical and monetary terms can be combined to produce so-called "hybrid" flow accounts. Emissions accounts for greenhouse gases are an example of the type included in this category.

Maintenance Expenditure account

The second category of accounts takes those elements of the existing SNA that are relevant to the good management of the environment and shows how the **environment-related transactions can be made more explicit**. An account of expenditures made by businesses, governments and households to protect the environment is an example of the accounts included in this category.

Environmental asset account

The third category of accounts in the SEEA comprises accounts for environmental assets measured in physical and monetary terms. Timber stock accounts showing opening and closing timber balances and the related changes over the course of an accounting period are an example.

SNA adjustment for impact on environment

The final category of SEEA accounts considers how the existing SNA might be adjusted to account for the impact of the economy on the environment. Three sorts of adjustments are considered; those relating to depletion, those concerning so-called defensive expenditures and those relating to degradation.

Scheme of the Report

We follow all three approaches as mentioned above: three pillar approach, ecological approach and capital theoretic approach.

Chapter II following three pillar approach presents status of West Bengal vis- a-vis all India regarding sustainability indicators. Methodology has been developed and presented in the chapter to do the same. This chapter demonstrates how along with available official published sources of statistics Composite sustainability indicator can also be constructed. This value addition from available statistics can be done with least effort and reported which is not done today. This will be useful to keep track of performances of states/districts and help in policy formulation within sustainable development paradigm.

Chapter III presents the methodology followed for preparation of water account.

Chapter IV presents the air account that could be attempted based on data using case study approach..

Chapter V summarises the methodological recommendations and the data requirements etc. for green accounting and satellite account preparation .

Chapter II

Three Pillar Approach

Towards a Composite Sustainability Index

The term 'Sustainable Development' is a broad concept and there are a number of definitions available. The World Commission on Environment and Development (the Brundtland Commission, 1987) defines it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This definition is perhaps the easiest and most acceptable one. Sustainable development recognizes the interdependence of environmental, social and economic systems. It promotes equality and justice through people empowerment. In the political aspect it demands broad based participation and democratic processes. The answer to the question that why sustainable development is important lies in the fact that by providing a new framework for decision-making, issues are considered from a multi-dimensional point of view. Success is measured not simply by the profit generated, but by the triple bottom line of economic prosperity, environmental stewardship and corporate social responsibility. Besides simply making good common sense, adhering to the principles of sustainable development fulfills compelling business needs as well, including reducing costs and liabilities, enhancing brand image and reputation, increasing customer loyalty, encouraging innovation and stimulating growth and strengthening with our communities (www.dow.com 1995-2004). The principles of sustainable development include fulfillment of human needs for peace, clean air and water, food, shelter, education and useful and satisfying employment. Environmental issues are important, such as ecological integrity through careful stewardship, reduction of wastes, and protection of diverse species and ecological systems. Sustainable development focuses on local people through public involvement in the definition and development of local solutions to environmental and development problems. Achievement of equity is attained through the fairest possible sharing of limited resources among contemporaries and between our generation and that of our descendents.

In the literature there are two concepts of sustainability: weak sustainability and strong sustainability. However, operationally it is the concept of weak sustainability that is used. It is not inconsistent with the experience of evolutionary process of human society. Sustainable development requires the maintenance of natural capital. By natural capital we mean natural resource stocks, land and ecosystem. If any pattern of development continues to deplete natural capital, then that development is not sustainable. The question that arises here is whether natural capital can be substituted by other forms of capital or not. The two conflicting views regarding the degree of substitutability between natural capital and other forms of capital are the weak and strong sustainability issues. Weak sustainability allows depletion of natural capital stock, so long as this depletion is offset by increase in the stock of other forms of capital. It assumes that all forms of capital are substitutes of one another. Strong sustainability, on the other hand, requires all forms of natural capital to be maintained independently of one another as it assumes that different forms of capital are complimentary to each other.

I. Indicators of Sustainable Development

To set sustainable development as an achievable goal, it is important to recognize the indicators of the same. A lot of effort has been given in this direction in the past decade. In 1992, governments of 178 countries met at Rio de Janeiro, Brazil, for the United Nations Conference on Environment and Development (UNCED). The Earth Summit, as UNCED was also known, was convened to address urgent problems of environmental protection and socio-economic development. The Commission of Sustainable Development (CSD, December 1992), which grew out of the Rio Summit, initiated a programme on sustainable development indicators in 1995. The programme resulted in a working list of one hundred and thirty four indicators (134) indicators. In order to assess the validity of these, twenty-two (22) countries from all over the world volunteered to test these indicators in an initiative that began in 1996. The indicators were tested according to individual countries own priorities and goals for sustainable development and implemented on the basis of common guidelines for national testing developed by the division for sustainable development in consultation with its indicators expert group. These countries subsequently met in 1999 to discuss experiences and best practices. In March 2000, under the direction of the Division of Sustainable Development and Department of Economic and Social Affairs (DSD/DESA), a small group of experts met to draft the final CSD framework. As a result of the meeting, a draft list of 58 indicators was selected and distributed to all testing countries for approval.

Though not one of the testing countries, India recognizes the importance of indicators and the work done by the Commission of Sustainable Development. It is to be appreciated, however, that the concepts, definitions and methodology underlying the well-known indicators vary, sometimes significantly, from country to country and over time within countries. There is also difference amongst countries in the way information is collected. (TERI 2000)

The principles of sustainable development underpin all government policies and in particular those on the economy, health, education, welfare, employment, social exclusion, transport, agriculture and the environment. Here comes the need for sustainable development indicators that present a balanced set of measures that will allow sustainable development to be assessed. But there is no international consensus yet on sustainable development indicators and no recommended shortlist of indicators although UNCSD has published a menu of about one hundred thirty five indicators that is being piloted by a number of countries.

II. Why need an Indicator?

An indicator helps to understand direction and enables to know the distance from the target. The indicator may point to an issue or condition. Faced with problems an indicator helps to determine what direction to take to address the issue. Indicators of a sustainable society point to areas where links between economy, environment and society are weak. We need indicators that give people an idea of whether or not their economy is getting worse or better. Indicators act as signals on development pathways to decision-makers so that the paths of unsustainable development can be avoided. While the idea of developing sustainable indicators is appealing, it is clear that the concept of sustainable development is broader than the measures used to describe it. Common to all research on sustainable development indicators, is the problem of identifying what to measure and how. Obviously the information for the indicators must be available. Similarly, the indicators that are developed must both be informative and revealing if sustainable development is being achieved, and act as an effective guide to policy-makers.

A good indicator may be considered to have the following properties:

i) easy to understand

ii) something that can be measured

iii) measure something believed to be important or significant in its own right

iv) the information it is calculated from should be readily available

v) there should be only a short time lag between the state of affairs referred to and the indicator becoming available

vi) based on information which can be used to compare different geographical areas or states.

vii) unit free to facilitate comparison over time and space

viii) one single value to provide unambiguous conclusion or guideline

III. Review of Literature on Sustainability Indicators

Quite a large number of literature concentrate on sustainability indicators' concepts and its types. A brief review of the existing literatures on sustainability indicators study will lead the way towards understanding the relevance and objective of the present study. There is no intention to refer to all the study relating to the present context rather, only selected references are being covered (as shown in Table 1), choice being governed by the variety of objectives and importance of the findings.

Table 1: List of Surveyed Literature

Indicators	Issues	Authors
	Strong Sustainability Issues	
	• To view economic, social and environmental efficiency as necessary towards sustainability • To view two or three partial indicators that stress on different aspect of the problem	Callens and Daniel (1999)
	Focus on Urban Sustainability Issues	
	• To focus on information	Button (2002)

	systems of all types in urban areas • To focus on feedback mechanisms including automatic mechanisms at the urban level • Integration of economic and environmental considerations	
Rural Sustainability Indicators		
• Protection and development of village commons • Sale of productive animals • Percentage of underprivileged people involved in development program to monitor ecological • Economic and social dimensions		Rangekar, Soni, Kakade (1999)
• Increased opportunity for wage employment • Expenditures on food intake • Wages higher than market rates • Access to gains of common land for poorest farmers • Enhancement in food grain security		Depinder Singh Kapur (1999)
• Index of habitat security based on farmers self analysis		Wicramsingh (1999)
• Factor productivity • Crop yields • Level of land degradation and deforestation		Katar Singh (1999)
• Land use changes • Biomass quality and quantity • Soil fertility • Energy efficiency		Ramakrishnan (1999)
Characteristics of Sustainability Indicators		
• Parsimony • Internal or external validity • Understandability by various user groups • Interconnectivity among different subsystems • Gender sensitivity		Gupta and Sinha (1999)
Criteria		
• Economic viability • Management of technology and knowledge		Mandavkar (1999)

• Equity for the sustainability and long term productivity of a natural resource management program		
• Dry zone criteria- transportation, energy, communication Socio-economic criteria- health, education, poverty eradication, agriculture		Zan U Thein Win (1999)
• Any measure of balance must look at measures integrated over time to document processes and trends • Relative weight to be given to different indicators		Dahl (1995)
• Value of natural capital plus manufactured should not be decreasing		Proops, Atkinson, Schlothein and Simon (1999)
Social Indicators		
• Percent of population living below poverty line • Gini index of income inequality • Unemployment rate • Ratio of average female wage to male wage • Nutritional status of children • Mortality rate under five years old • Infant mortality rate • Life expectancy at birth • % Population with adequate swage disposal facilities • Population with access to safe drinking water • % Population with primary health acre facilities • Immunization against infectious childhood diseases • Contraceptive prevalence rate • Children reaching grade five of primary education • Adult secondary education achievement level • Adult literacy rate • Floor area per person • Number of reported crimes per thousand population • Population growth rate • Sex ratio		TERI (2000)

• Crude birth rate • Population of urban formal and informal settlements		
Economic Indicators		
• GDP per capita • Investment share in GDP • Balance of trade in goods and services • Debt to GNP ratio • Official development assistance (ODA) given or received as % of GNP • Fiscal deficit • Intensity of material consumption • Annual energy consumption per capita • Share of consumption of renewable energy sources • Energy use per unit of GDP (energy intensity) • Energy use per unit of GDP (energy intensity) by sector (commercial, services, manufacturing, transportation and residential) • Intensity of energy use: transportation • Energy imports (proposed) • Distance traveled per capita by mode of transport		TERI. (2000)
Environmental Indicators		
• Emissions of greenhouses gases • Consumption of ozone depleting substances (ODS) • Ambient concentration of air pollutants in urban area • Arable and permanent cropland • Per hectare food grain production (proposed) • % Of gross cropped area irrigated (proposed) • Use of fertilizers • Use of agricultural pesticides per unit of agricultural land area		TERI. (2000)

• Forest area as a % of land area • Wood harvesting intensity • Land affected by desertification • Area of urban formal and informal settlements • Algae concentration in coastal waters • % Of total population living on coastal areas • Annual catch by major species • Annual withdrawals of ground and surface water as a % of total renewable water • Biochemical oxygen demand in water bodies • Concentration of faecal coliform in freshwater • Area of selected key ecosystems • Protected area as a % of land area • Abundance of selected key species • Generation of industrial and municipal solid waste • Generation of hazardous waste (including hospital waste) • Generation of radioactive waste • Waste recycling and reuse		
Institutional Indicators		
• National sustainability development strategy • Implementation of ratified global agreements • Number of internet subscribers per 1000 inhabitants • Main telephone lines per 1000 inhabitants • Expenditure on R&D as a % of GDP		TERI (2000)

The article Sustainable Measures: Indicators of Sustainability; what is an Indicator of Sustainability?[1] (2000) states that sustainability indicators reflect the reality that different segments of society are interrelated. Sustainability requires integrated view

[1] www.sustainablemeasures.com/indicators

of the world - it requires multidimensional indicators that show links among community's economy, environment and society.

In the paper Sustainable Measures: Indicators of Sustainability; characteristics of effective indicators[2] (2000) indicators have been referred to as proxies or substitutes for measuring conditions that are so complex that there is no direct measurement. Indicators have been stated as quantifiable. An indicator is not the same thing as an indication, which is generally not quantifiable.

In the paper edited by Gupta and Sinha (1999), they have talked of additional properties of a good indicator like parsimony, internal or external validity, understandability by various user groups, inter-connectivity among different sub-systems, and gender sensitivity. Many authors have come up with very specific indicators. Some of these focus on rural specificity. Here *Rangekar, Soni and Kakade (1999)* have described indicators of sustainable rural development which are protection and development of village commons, sale of productive animals and percentage of underprivileged people involved in the development program to monitor ecological, economic and social dimensions. *Depinder Singh Kapur(1999)* considered degree of livelihood support of rural people and poor farmers and his suggested indicators are increased opportunity for wage employment, expenditures on food intake, wages higher than market rates, access to gains of common land for poorest households and enhancement in food grain security. *Wickramsingh(1999)* introduced a measure of sustainability of rural development termed as index of habitat security based on farmers self analysis in Kelegama district of Sri Lanka. He has also studied in the context of Sri Lanka that literacy level and life expectancy have increased and level of infant and maternal mortality has decreased. *Katar Singh(1999)* focused on indicators such as factor productivity, crop yields, level of land degradation and deforestation. We also found mention of ecological indicators such as land use changes, biomass quality, water quality and quantity, soil fertility and energy efficiency by *Ramakrishnan,(1999)* who has also noted that the indicators quality of life, health and hygiene, nutrition and food security and morbidity

[2] www.sustainablemeasures.com/characteristics

symptoms are useful for ascertaining the social status of society. *Malhotra(1999)* clarified the definition of social sustainability and elaborated the concept. *Mandavkar(1999)* enumerated three criteria for indicators that are economic viability, management of technology and knowledge, equity for the sustainability and long-term productivity of a natural resource management program. All these indicators can be classified under social indicators. *Mathew Sarvina(1999)* traced historical background of the development scenario in Seychelles islands. *Zan U Thein Win(1999)* of Myanmar emphasized on strengthening of human resources and social development. Criteria and indicators have been discussed for the development of dry zones. Criteria for the dry zone are transportation, energy, and communication while that for socio-economic development are health, education, poverty eradication, agriculture etc. *Ms Monfarad(1999)* highlights role of rural and pastoral women of Iranian republic in respect of rural development. She suggested the need to adopt policies to train rural and pastoral women in agricultural and environmental issues and develop policies to eliminate health hazards.

TERI Project Report (2000) reviews the indicators prepared by the Commission of Sustainable Development (1992) from a developing country perspective. The paper comments on the significance of the indicators as they relate to India and where required new modifications have been proposed. An effort has been made to bring out any differences in the national definitions or methodologies vis-à-vis the CSD. The indicators presented in the article have been classified into social, environmental, economic and institutional as per the classification of the CSD (1992).

Callens and Daniel (1999) state that firms should play an important role in the attainment of sustainability goals due to their central role in human activities and development. The paper contributes to the methodology of indicators that allow for the assessment of business participation into sustainable development. A fundamental standpoint is to view economic, social and environmental efficiency as a necessary step towards sustainability.

Hanley, Moffatt, Faichney, and Wilson (1999) present results from a time series analysis of seven alternative measures of sustainability for Scotland. The measures chosen are Green net national product, Genuine savings, Ecological footprint, Environmental space, Net primary productivity, Index of sustainable economic welfare and Genuine progress indicator. These are all measures at the national or macro level. It has been noted that no one single measure of sustainability is likely to be sufficient.

Proops, Atkinson, Schlotheim, and Simon (1999), state a simple and minimal criteria for sustainability, that is the value of natural capital plus manufactured capital should not be decreasing. On the basis of any individual country or region, the above simple comparison may be misleading, as it does not take into account the production of goods for consumption in other countries or region, via international trade. A method of calculating a weak sustainability criterion has been established for both the 'closed' economy approach and the 'open' economy approach.

The aim of the paper by Button (2002) is to focus on the local environmental effects of urbanization and to consider ways in which they may be effectively treated within the confines of an isolated city context and more generally when urban areas are seen as part of a wider economic system.

Commission on Sustainable Development[3] has adopted a work program on indicators for use by countries in measuring their own progress towards sustainable development. The OECD, one of the pioneers in indicator work has adopted has adopted a new focus on sustainable development. The multiple facets of complex environmental / developmental problems require many indicators to assure experts that all critical factors are being followed. It is not yet clear what is important or measurable with indicators to address a particular problem. Systems model would be required to understand and identify those large-scale systems parameters for which indicators should be developed.

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[3] Current status of indicator work (www.earthwatch.unep.net)

In order to produce effective indicators of sustainable development, one must agree on what one is trying to indicate. Dahl[4] (1995) states that the challenge in developing indicators of sustainability is to find simple ways of presenting their concept despite the complexity and uncertainty. To incorporate the sense of time, a new kind of accounting, bringing in the temporal dimension is introduced which is called 'chrono-economics'. Any measure of balance must look at measures integrated over time to document processes and trends. Also, relative weights should be assigned to different indicators. Indicator values can be ranged on a non-linear scale, where more extreme problems or larger deviations from the desirable level carry more weight than small deviations.

Prugh and Assadourian (2003) are of the opinion that carrying capacity for humans are in large part self-defined, because the limit on human population is not the maximum carrying capacity, but the cultural carrying capacity, which is lower. If everyone lives at a subsistence level, the earth will support more people than if everyone lives at a more comfortable level that requires more resources. The choices we are making now are placing a heavy load on the earth's capacity to support us. By one measure, the Ecological Footprint, we are now exceeding that capacity by about 20%. The margin will widen, probably at an accelerating rate, as our numbers and consumption rise.

IV Objective of the Study and Data Source

From a brief review of the existing literature on indicators of sustainable development, we see that the multiplicity of sustainability indicators can be grouped into two types, which may be environmental and non environmental. The environmental indicators are those that provide an overall assessment of the environment and they may also point to the environmental stresses caused by anthropogenic and other factors. The non-environmental indicators comprise of the social and economic indicators. The social indicators reflect various human development aspects and they provide the yardstick for progress of human life. In the emerging paradigm of development these are all indispensable without which

[4] www.earthwatch.unep.net

attainment of sustainability is impossible. However, as mentioned in Section II, the real challenge is to come up with a single measurable unit free indicator. In this article our objectives are to:

- suggest a methodology to construct a single index, namely the ‘Composite Sustainability Index’ (CSI)
- apply the suggested methodology to evaluate the performance of the states and union territories of India in their progress towards sustainability
- trace the movement of the states and union territories on the sustainable development pathway.
- identify policy priorities to put a state on the sustainable development pathway

As part of the empirical test of our indicator analysis we have collected statistical data from various secondary sources. We have referred to various statistical abstracts, census reports, human development reports and a host of other reports, journals and periodicals pertaining to different years for the states and union territories of India. Subject to data availability, we have selected a list of indicators, as shown in Table 2, for our study. Some of the indicators are positive while others are negative with respect to contribution to achieving sustainability. That indicator, an increase in whose value helps the states and union territories to move towards the goal of achieving sustainability, is known as a positive indicator of sustainability. Whereas that indicator, an increase in whose value causes the states and union territories to move away from the goal of achieving sustainability, is known as a negative indicator of sustainability. Table 2 shows the relevant classification of the sustainability indicators. Detailed data set and gaps are available with the authors and may be accessed upon request.

Table 2: Indicators and their Status in Sustainability Index

Social	**The more the value than India’s average, the better (positive)**	**The less the value than India’s average, the better (negative)**
Population living below poverty line		*
Population with access to safe drinking water	*	

Sex ratio	*	
Literacy rates	*	
Infant mortality rate		*
Crude birth rate		*
Life expectancy	*	
Crime against children		*
Crime against women		*
Reported cases of polio		*
Environmental		
Area under foodgrains	*	
Gross cropped area	*	
Gross irrigated area	*	
Fertilizer consumption		*
Use of pesticides		*
Forest area	*	
Wetlands	*	
Protected area	*	
Concentration of air pollutants in million plus cities		*
Reported cases of asthma		*
Reported cases of malaria		*
Reported cases of diarrhoea		*
Reported cases of dengue		*
Reported cases of whooping cough		*
Economic		
GDP	*	
Fiscal deficit		*
Consumption of electricity	*	
Investments (Industry, agriculture, education)	*	

V. Composite Sustainability Index: A Methodology for Evaluating Relative Performance of the States

We intend to construct the desired CSI from the list of component indicators of sustainability (see Table 2). While constructing the CSI, first we formulate a ‘benchmark’ or ‘baseline’ to evaluate the relative distance (a primary desideratum of the sustainability indicators) of the states and union territories in terms of the sustainability performances. Our goal will be achieved if we can assign numerical values and assess the relative positions of the states and union territories with respect to the benchmark. Conceptually we have taken the 'all India sustainability performance' level as that benchmark. The benchmark that we need to formulate must satisfy some important properties such as:

i) It is quantifiable
ii) It is unit free, which makes it's comparisons with the performances of the states and union territories simple, measurable and comparable across time and space.
iii) It acts as a quantification of the performances of the states and union territories.
iv) It is dynamic by nature. This means that with changing performance, the benchmark also need to shift.

In constructing the benchmark, we have drawn from the literature the concept of 'Representation Index' (R.I.). Representation Index measures the equality or inequality of distribution on the basis of relative shares of different groups (Pscharopoulos & Woodhall, 1985, Roy & Majumdar, 1994 and Majumdar, 1995). It indicates whether a particular group or area is over represented or under represented in relation to the total population. In the present context, the RI helps in quantifying the relative distance of the states in India's overall performance in achieving sustainability. State wise RI is a simple device that indicates whether a particular state is pulling up or pushing down the level of India's performance.

We assume the relation between the RI and the sustainability status of each state concerned as shown in Table 3.

Table 3: Relation between RI and Sustainability Status

Representation Index	Sustainability Status
Value > Benchmark	Positive
Value < Benchmark	Negative

There will be RIs for each state and for each component of the social, economic and the environmental indicators (Table 2). So there will be (28 x 35) = 980 RIs for the twenty eight indicators and thirty five states and union territories of India. For all the social, economic and some select environmental indicators like air quality status and diseases, we use the formula

(1) *RI = (percentage share of the component indicator of the* i^{th} *state)/ (percentage share of population of that state)*100*.

For example, for literacy rate,

(1a) *RI = (percentage share of literacy rate of the* i^{th} *state)/ (percentage share of population of that state)*100*

(1b) *Benchmark RI = (percentage share of the component indicator of India)/ (percentage share of total population of India)*100.*

While calculating the representation indices of some of the environmental indicators like gross cropped area, protected area, wetlands and forest area we use the formula

(2) *RI = (percentage share of the component indicator of the* i^{th} *state)/ (percentage share of total geographical area of that state)*100.*

(2a) *Benchmark RI = (percentage share of the component indicator of India)/ (percentage share of total geographical area of India)*100.*

Similarly while calculating the representation indices of the remaining environmental indicators like area under foodgrains, consumption of chemical fertilizers, consumption of pesticides and gross irrigated area, we use the formula

(3) *RI = (percentage share of the component indicator of the* i^{th} *state)/ (percentage share of gross cropped area of that state)*100.*

(3a) *Benchmark RI = (percentage share of the component indicator of India)/ (percentage share of total gross cropped area of India)*100.*

There will be twenty eight benchmarks for each of the component indicators. Using the twenty eight benchmarks and the (28 x 35) = 980 RIs we estimate the 'Relative Representation Index' (RRI). We calculate the RRI to assign a score to every state and union territory for each indicator. The RRI score of any state for a particular indicator gives the deviation of that state from the benchmark RI. If the RRI score is positive, then the state will have a positive sustainability status and vice versa. Whereas, if the RRI score is zero, then the state will be exactly at par with the benchmark. The formula for calculating RRI is,

(4) *RRI = RI – value of benchmark RI*

While calculating the RRI scores by the formula 4, we find that the scores can be positive, zero or negative, depending on the deviation from the benchmark. But we know that some of the indicators inherently contribute positively to sustainability (for example, literacy rate; more is the value, better is the position of the state or the union territory in achieving sustainability, as mentioned in Table 2), while some contribute negatively (for example, infant mortality rate; more is the value, worse is the position of the state or union territory in achieving sustainability). So to make the indicators bias free of inherent positive or negative contribution to sustainability, we need to redefine RRI.

For positive indicators like literacy rate, we have used Formula 4.

For negative indicators like infant mortality rate, we have used the formula

(4a) *RRI = value of benchmark RI – value of the RI*

There will be (28 x 35) = 980 RRI scores which can be either positive, zero or negative. The RRI scores are used to construct Semi Composite Indices (SCI), namely the 'Composite Social Index' (CSCI) using the social sustainability indicators, the 'Composite Environmental Index' (CENI) using the environmental sustainability indicators and the 'Composite Economic Index' (CECI) using the economic sustainability indicators. By a simple summation of the ten social, fourteen environmental and four economic RRI scores we get the SCIs. The relevant formulae are:

(5) $CSCI = ?\ RRI_j$; j = 1(1)10 ; RRI_j being the RRI of the j^{th} social indicator.

(6) $CENI = ?\ RRI_j$; j = 1(1)14 ; RRI_j being the RRI of the j^{th} environmental indicator.

(7) $CECI = ?\ RRI_j$; j = 1(1)4 ; RRI_j being the RRI of the j^{th} economic indicator.

These three semi composite indices can now be used to estimate the ranks of the states and union territories. Each state and union territory gets three sets of ranks which give us a good idea about the positions of the states and union territories on the social, environmental and economic sustainable development pathways respectively. We will get three SCIs for each state and union territory and thus (3 x 35) = 105 SCIs for all the states and union territories taken together.

We have already mentioned in Section IV that to know about the positions of the states and union territories on the overall sustainable development pathway, we need one single evaluative criterion for each state and union territory like the CSI. To arrive at the CSI we can now add the RRI scores of all the twenty-eight indicators of sustainability. The formula used is:

(8) $CSI = CSCI + CENI + CECI$

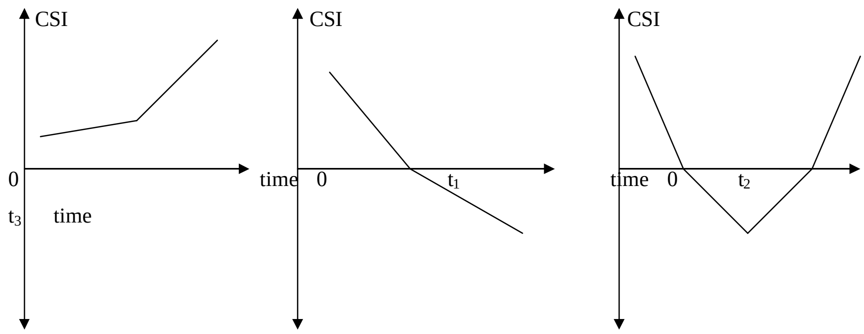
$= ?\ RRI_j$; j =1(1)28 ; RRI_j being the RRI of the j^{th} indicator

Proceeding from equation (1) through (8) we have defined a methodology to arrive at one single index, namely the 'CSI' for each state and union territory. So there will be thirty five CSI values which are pure numbers and comparable over time and space. The values of the CSI for the different states and union territories can be either positive or negative. This is because computationally the values of the individual RRI scores can be either positive or negative or even zero. Conceptually that state or union territory, for which the value of the CSI is positive, can be said to be on the path to achieving sustainability. Whereas that state or union territory, for which the respective value is negative, can be considered as away from the sustainable development pathway and is in need for policy intervention which will place it on the same. There can be a possibility of deviation from the sustainable development pathway. This may happen due to several reasons. It may be imagined that air pollution is not monitored appropriately, thus gradually leading to a point beyond permissible limits and hence the state may be showing an unsustainable growth path. We assume 'zero' CSI to be the switch point of a state or a union territory on their pathway to sustainability (Figure 1). The objective of every state and union territory should be to constantly make efforts to attain positive CSI value. The steps in the derivation of the thirty five CSIs are shown in Table 4.

Table 4: Indices used in the study

Indices	Numbers
Representation Indices	(28 x 35) = 980
Relative Representation Indices	(28 x 35) = 980
Semi Composite Indices	(3 x 35) = 105
Composite Sustainability Indices	(1 x 35)= 35

In figure 1 we have tried to illustrate conceptually the switch point and the possible sustainable development pathways based on the values of the CSI. The positive values of the CSI are plotted along the vertical axis above zero, while the negative values are plotted below zero. Time periods are plotted along the horizontal axis.



1.i)no switch point 1.ii)single switch point at 't_1' 1.iii)multiple switch points at 't_2'&'t_3'

Fig 1(i) shows the case where the CSI values of the state remain positive overtime. Hence the state is on sustainable development pathway consistently without a switch point. An upward movement of the graph indicates an increase in the value of the CSI and vice versa. In Fig 1(ii), the CSI value of the state was initially positive, then decreased to be zero and finally turned negative. Hence we have a single switch point at time t_1. In Fig 1(iii), the CSI value was initially positive, then decreased to turn negative and finally increased to turn positive once again. So here we have two switch points, first at time t_2, where the CSI value turned negative and then at time t_3, where the CSI value turned positive once again. The target of the states and union territories should be to remain in the N-E quadrant always.

VI. Composite Sustainability Index: An Empirical Investigation

We have estimated for India all the representation indices, the relative representation indices, the semi composite indices and the composite sustainability indices as shown in Table 4. All the relevant calculations and tables are shown in the Annexure (Tables A2 through A33). For analysis based on these detailed tables we have prepared some summary tables which we present in the text below. We have analyzed these results by categorizing the states and union territories by their sustainability status and relative ranking in terms of the RRIs, the semi composite indices and the CSI. All these ranks are based on the numerical values of the RRIs as mentioned in the annexure.

We have taken data of the years 1990-’91, 1995-’96 and 2000-’01 for India. Values of the representation indices of the individual sustainability indicators show that all states are not equal in terms of performance level. Status of some of them is positive while that of others are negative. In case of positive indicators (see Table 2), status of states whose values of representation indices are more than that of the benchmark, have been designated as ‘positive’ and vice versa. Similarly for negative indicators, status of states whose values of representation indices are more than that of the benchmark, have been designated as ‘negative’ and vice versa. So, the states and union territories whose status in sustainability is positive can be considered to be performing better in achieving sustainability than the ones whose status is negative.

We have prepared individual tables for every indicator indicating the representation status of the states. We have also indicated the states and union territories for which data is not available or there have not been any reported cases. Non-availability of data means that data is not available, maybe due to the fact that census has not been carried out or for some other reasons. On the other hand, 'no reported cases' means that the number of cases reported is zero. This may be due to missing data, or the fact that the number of cases occurred has actually been zero. However, both 'non availability of data' and 'no reported cases' can together be referred to as data gaps. But non-availability of data of the states of Chattisgarh, Jharkhand and Uttaranchal for the years prior to 2000 should not be regarded as data gaps since these three states were created from the states of Madhya Pradesh, Bihar and Uttar Pradesh respectively in the year 2000 only.

VI.I Sustainability status evaluated through RIs

As mentioned in Table 4, we have calculated (28 x 35) RIs out of which (10 x 35) = 350 are for the ten social indicators, (14 x 35) = 490 are for environmental indicators and the remaining (4 x 35) = 140 are for economic indicators.

VI.I.I Social indicators

All the social indicators of sustainability (Tables 5 to 14) have been scaled with respect to total population while calculating the respective RIs.

Table 5: Population below Poverty Line

Sustainability Status	1988	1994	2000
Positive	Andhra Pradesh, Arunachal Pradesh, Assam , Goa, Gujarat, Haryana, Himachal Pradesh, J&K,Karnataka, Kerala, Manipur, Meghalaya, Mizoram, Nagaland, Punjab, Rajasthan, Sikkim, Tripura,	Andhra Pradesh, Goa, Gujarat, Haryana, Himachal Pradesh, J&K, Karnataka, Kerala, Manipur, Mizoram, Punjab, Rajasthan, Tamil Nadu, A&N Islands, Chandigarh,	Andhra Pradesh, Goa, Gujarat, Haryana, Himachal Pradesh, J&K, Karnataka, Kerala, Maharashtra, Mizoram, Punjab, Rajasthan, Tamil Nadu, A&N Islands, Chandigarh,

	Chandigarh, Delhi, Lakshadweep	Daman &Diu, Delhi, Lakshadweep	D&NH, Daman &Diu, Delhi, Lakshadweep, Pondicherry
Exact	India	India, West Bengal	India
Negative	Bihar, Madhya Pradesh, Maharashtra, Orissa, Uttar Pradesh, Tamil Nadu, West Bengal, A&N Islands, D& NH, Pondicherry	Arunachal Pradesh, Assam, Bihar, Madhya Pradesh, Maharashtra, Meghalaya Nagaland, Orissa, Tripura, Uttar Pradesh, Sikkim, D&NH, Pondicherry	Arunachal Pradesh , Assam, Bihar, Madhya Pradesh, Manipur, Meghalaya, Nagaland, Orissa, Sikkim, Tripura, Uttar Pradesh, **West Bengal,**
Non availability of data / No reported cases	Chattisgarh, Jharkhand, Uttaranchal, Daman & Diu	Chattisgarh, Jharkhand, Uttaranchal	Chattisgarh, Jharkhand, Uttaranchal

The unique case here is that of West Bengal, who had improved its status in 1994 to move alongside with India, but slipped back to lower status in 2000. The reason is that though West Bengal has done a good job in lowering the percentage of people below poverty line between 1987-88 and 2000, the performances of other states with positive sustainability status have been relatively better.

Table 6: Population with Access to Safe Drinking Water

Sustainability Status	1991	2001
Positive	Arunachal Pradesh, Gujarat, Haryana, Himachal Pradesh, Karnataka, Maharashtra, Punjab, Sikkim, Tamil Nadu, West Bengal, A&N Islands, Chandigarh, Daman &Diu, Delhi, Pondicherry	Andhra Pradesh, Arunachal Pradesh, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Maharashtra, Punjab, Tamil Nadu, Uttar Pradesh, Uttaranchal, **West Bengal**, Chandigarh, Daman &Diu, Delhi,

		Pondicherry
Exact	India, Uttar Pradesh	India, A&N Islands, D&NH
Negative	Andhra Pradesh, Assam, Bihar, Goa, Kerala, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Rajasthan, Tripura, D&NH, Lakshadweep	Assam, Goa, Jharkhand, J&K, Kerala, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Rajasthan, Sikkim, Tripura, Lakshadweep
Non availability of data / No reported cases	Chattisgarh, Jharkhand, Uttaranchal, J&K	Chattisgarh

Andhra Pradesh, Bihar, Uttar Pradesh and Dadra & Nagar Haveli have bettered their positions in 2001 as compared to 1991. Performances of these states have been relatively better than the other states in the negative sustainability status category. The percentages of people having access to safe drinking water in Sikkim and Andaman & Nicobar Islands have not increased significantly in the nineties and hence these states have slipped to the lowest status in 2001.

Table 7: Sex Ratio

Sustainability Status	1991	2001
Positive	Andhra Pradesh, Goa, Gujarat, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Manipur, Meghalaya, Orissa, Tamil Nadu, Tripura, D&NH, Daman &Diu, Lakshadweep, Pondicherry	Andhra Pradesh, Chattisgarh, Goa, Himachal Pradesh, Karnataka, Kerala, Manipur, Meghalaya, Orissa, Tamil Nadu, Tripura, Uttaranchal, Lakshadweep, Pondicherry
Exact	India, Assam, Mizoram, West Bengal	India, Assam, Jharkhand, Mizoram, **West Bengal**
Negative	Arunachal Pradesh, Bihar, Haryana, J&K, Madhya Pradesh, Nagaland, Punjab, Rajasthan, Sikkim, Uttar Pradesh, A&N	Arunachal Pradesh, Bihar, Gujarat, Haryana, J&K, Madhya Pradesh, Maharashtra, Nagaland, Punjab, Rajasthan, Sikkim,

	Islands, Chandigarh, Delhi	Uttar Pradesh, A&N Islands, Chandigarh, D&NH, Daman &Diu, Delhi
Non availability of data / No reported cases	Chattisgarh, Jharkhand, Uttaranchal	

The sex ratios of Maharashtra, Dadra & Nagar Haveli and Daman & Diu have declined in the nineties. Hence these three states and union territories have dropped down in status.

Table 8: Adult Literacy Rates

Sustainability Status	1991	1995	2001
Positive	Assam, Goa, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Manipur, Mizoram, Nagaland, Punjab, Sikkim, Tamil Nadu, Tripura, West Bengal, A&N Islands, Chandigarh, Daman &Diu, Delhi, Lakshadweep, Pondicherry	Assam, Goa, Gujarat, Haryana, Himachal Pradesh, Kerala, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Punjab, Sikkim, Tamil Nadu, Tripura, West Bengal, A&N Islands, Chandigarh, D&NH, Daman &Diu, Delhi, Lakshadweep, Pondicherry	Goa, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Manipur, Mizoram, Nagaland, Punjab, Sikkim, Tamil Nadu, Tripura, Uttaranchal, **West Bengal**, A&N Islands, Chandigarh, Daman &Diu, Delhi, Lakshadweep, Pondicherry
Exact	India	India	India, Chattisgarh
Negative	Andhra Pradesh,, Arunachal Pradesh, Bihar, Madhya Pradesh, Meghalaya, Orissa, Rajasthan, Uttar Pradesh, D&NH	Andhra Pradesh,, Arunachal Pradesh, Bihar, J&K, Karnataka, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh	Andhra Pradesh,, Arunachal Pradesh, Assam, Bihar, J&K, Jharkhand, Madhya Pradesh, Meghalaya, Orissa, Rajasthan, Uttar Pradesh, D&NH
Non availability of data / No reported cases	Chattisgarh, J&K, Jharkhand, Uttaranchal	Chattisgarh, Jharkhand, Uttaranchal	

Literacy rates of Meghalaya and Dadra & Nagar Haveli had increased in mid nineties but went down in 2001 due to a lack of sustained efforts. Hence their status had improved in the mid nineties but slipped back to the negative sustainability status category in 2001. Assam has performed poorly in the late nineties and has gone down in status in 2001. The literacy rate of Karnataka had dropped in 1995 but due to renewed efforts has increased significantly in 2001. Hence the status of the state, after slipping down in 1995, has improved in 2001.

Table 9: Infant Mortality Rate

Sustainability Status	**1991**	**1995**	**2001**
Positive	Andhra Pradesh, Bihar, Gujarat, Haryana, Kerala, Maharashtra, Punjab, Tamil Nadu, West Bengal	Andhra Pradesh, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Punjab, Tamil Nadu, West Bengal	Arunachal Pradesh, Bihar, Goa, Gujarat, Himachal Pradesh, J&K, Jharkhand, Karnataka, Kerala, Maharashtra, Manipur, Mizoram, Meghalaya, Punjab, Sikkim, Tamil Nadu, Tripura,Uttaranchal, **West Bengal,** A&N Islands, Chandigarh, D&NH, Daman &Diu, Delhi, Lakshadweep, Pondicherry
Exact	India, Himachal Pradesh	India	India
Negative	Assam, Karnataka, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh	Assam, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh	Andhra Pradesh, Assam, Chattisgarh, Haryana, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh
Non availability of data / No reported cases	Arunachal Pradesh, Chattisgarh, Goa, J&K, Jharkhand, Manipur, Mizoram, Meghalaya, Nagaland, Sikkim,	Arunachal Pradesh, Chattisgarh, Goa, J&K, Jharkhand, Manipur, Mizoram, Meghalaya, Nagaland, Sikkim,	Nagaland

	Tripura, Uttaranchal, A&N Islands, Chandigarh, D&NH, Daman &Diu, Delhi, Lakshadweep, Pondicherry	Tripura, Uttaranchal, A&N Islands, Chandigarh, D&NH, Daman &Diu, Delhi, Lakshadweep, Pondicherry	

Due to non-availability of data, an inter temporal comparison of the positions of a large number of states could not be carried out. Amongst the others, infant mortality rates in Andhra Pradesh and Haryana have decreased in 2001 with respect to 1991, but that in other states in the positive sustainability status category has decreased by a relatively greater extent. Hence these two states have gone down in status in 2001. Infant mortality rates in Himachal Pradesh and Karnataka have decreased significantly through the nineties and hence this has helped them in improving their status in 1995.

Table 10: Reported Cases of Polio

Sustainability Status	2001
Positive	Assam, Gujarat, Haryana, Jharkhand, Maharashtra, Punjab, **West Bengal**, Delhi
Exact	India
Negative	Bihar, Uttar Pradesh, Uttaranchal
Non availability of data / No reported cases	/ Andhra Pradesh, Arunachal Pradesh, Chattisgarh, Goa, Himachal Pradesh, J&K, Karnataka, Kerala, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Rajasthan, Sikkim, Tamil Nadu, Tripura, A&N Islands, Chandigarh, D&NH, Daman &Diu, Lakshadweep, Pondicherry

Table 11: Crude Birth Rate

Sustainability Status	1991	1995	2001
Positive	Andhra Pradesh, Goa, Gujarat, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Manipur, Nagaland, Punjab,	Andhra Pradesh, Arunachal Pradesh, Goa, Gujarat, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Manipur, Punjab,	Andhra Pradesh, Arunachal Pradesh, Goa, Gujarat, Himachal Pradesh, J&K, Karnataka, Kerala, Maharashtra,

	Sikkim, Tamil Nadu, Tripura, West Bengal, A&N Islands, Chandigarh, Daman &Diu, Delhi, Lakshadweep, Pondicherry	Sikkim, Tamil Nadu, Tripura, West Bengal, A&N Islands, Chandigarh, Daman &Diu, Delhi, Lakshadweep, Pondicherry	Manipur, Mizoram, Orissa, Punjab, Sikkim, Tamil Nadu, Tripura, Uttaranchal, West Bengal, A&N Islands, Chandigarh, Daman &Diu, Delhi, Lakshadweep, Pondicherry
Exact	India, Orissa	India	India
Negative	Arunachal Pradesh, Assam, Bihar, Haryana, Madhya Pradesh, Meghalaya, Rajasthan, Uttar Pradesh, , D&NH	Assam, Bihar, Haryana, Madhya Pradesh, Meghalaya, Orissa, Rajasthan, Uttar Pradesh, D&NH	Assam, Bihar, Chattisgarh, Haryana, Jharkhand, Madhya Pradesh, Meghalaya, Rajasthan, Uttar Pradesh, D&NH
Non availability of data / No reported cases	Chattisgarh, J&K, Jharkhand, Mizoram, Uttaranchal	Chattisgarh, J&K, Jharkhand, Mizoram, Nagaland, Uttaranchal	Nagaland

Crude birth rate of Arunachal Pradesh has fallen significantly between 1991 and 2001, thus helping the state to move up in status. Fall in crude birth rate of Orissa had been marginal between 1991 and 1995 whereas the same in the other states in the positive sustainability status category had been relatively more and hence Orissa had dropped down to the negative sustainability status category in 1995. However between 1995 and 2001 crude birth rate of the state dropped significantly, thus helping it to move back to the positive sustainability status category in 2001.

Table 12: Life Expectancy

Sustainability Status	1992	2001
Positive	Andhra Pradesh, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Punjab, Tamil Nadu, West Bengal	Haryana, Kerala, Maharashtra, Punjab, Tamil Nadu, **West Bengal**
Exact	India	India, Bihar, Karnataka

Negative	Assam, Bihar, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh	Andhra Pradesh, Assam, Gujarat, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh
Non availability of data / No reported cases	Arunachal Pradesh, Chattisgarh, Goa, J&K, Jharkhand, Manipur, Mizoram, Meghalaya, Nagaland, Sikkim, Tripura, Uttaranchal, A&N Islands, Chandigarh, D&NH, Daman &Diu, Delhi, Lakshadweep, Pondicherry	Arunachal Pradesh, Chattisgarh, Goa, Himachal Pradesh, J&K, Jharkhand, Manipur, Mizoram, Meghalaya, Nagaland, Sikkim, Tripura, Uttaranchal, A&N Islands, Chandigarh, D&NH, Daman &Diu, Delhi, Lakshadweep, Pondicherry

Here also, inter temporal comparison is not possible because data is not available for a large number of states. Amongst the others, both male and female life expectations in the states of Andhra Pradesh, Gujarat and Karnataka have increased, but by a relatively lesser magnitude with respect to the other states of positive sustainability status category between 1992 and 2001. Hence they have gone down in status. Life expectation in Bihar, on the other hand has increased significantly in the period under consideration and hence this state has moved up in status in 2001.

Table 13: Crime against Children

Sustainability Status	1996	2001
Positive	Andhra Pradesh, Assam, Bihar, Goa, J&K, Karnataka, Kerala, Manipur, Meghalaya, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal, A&N Islands, Chandigarh, Pondicherry	Andhra Pradesh, Assam, Bihar, J&K, Jharkhand, Karnataka, Kerala, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Uttaranchal , West Bengal, Pondicherry
Exact	India	India
Negative	Arunachal Pradesh, Gujarat, Haryana, Himachal Pradesh, Madhya Pradesh, Maharashtra, Mizoram, Delhi	Chattisgarh, Goa, Gujarat, Haryana, Himachal Pradesh, Madhya Pradesh, Maharashtra, Uttar Pradesh, Chandigarh, Delhi, Lakshadweep

Non availability of data / No reported cases	Chattisgarh, Jharkhand, Uttaranchal / Nagaland, Dadra & Nagar Haveli, Daman & Diu, Lakshadweep	/ Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Andaman & Nicobar Islands, Dadra & Nagar Haveli, Daman & Diu

Total reported crimes against children have increased drastically in the states of Goa, Uttar Pradesh and Chandigarh and hence they have gone down in status in 2001 as compared to 1996.

Table 14: Crime against Women

Sustainability Status	2001
Positive	Bihar, Chattisgarh, Gujarat, Jharkhand, Karnataka, Maharashtra, Manipur, Meghalaya, Nagaland, Punjab, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, Uttaranchal**, West Bengal**, D&NH, Daman &Diu, Pondicherry
Exact	India, Haryana, A&N Islands
Negative	Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Himachal Pradesh, J&K, Kerala, Madhya Pradesh, Mizoram, Orissa, Rajasthan, Chandigarh, Delhi
Non availability of data / No reported cases	/ Lakshadweep

VI.I.II Environmental indicators

Tables 15 to 28 show the sustainability status of the states and union territories for the different environmental indicators that we are working with.

Table 15: Area under Foodgrains

Sustainability Status	1991	1996	2000
Positive	Arunachal Pradesh, Assam, Bihar, Goa, Himachal Pradesh, J&K, Madhya Pradesh, Manipur, Mizoram, Nagaland, Orissa, Punjab, Sikkim, Tamil Nadu,	Arunachal Pradesh, Assam, Bihar, Haryana, Himachal Pradesh, J&K, Madhya Pradesh, Manipur, Mizoram, Nagaland, Orissa, Punjab, Uttar Pradesh, West	Arunachal Pradesh, Assam, Bihar, Chattisgarh, Haryana, Himachal Pradesh, J&K, Jharkhand, Karnataka, Manipur, Punjab, Uttar Pradesh,

	Tripura, Uttar Pradesh, West Bengal, Delhi	Bengal, D&NH, Daman & Diu, Delhi, Pondicherry	Uttaranchal, D&NH, Daman & Diu, Delhi, Pondicherry
Exact	India	India	India
Negative	Andhra Pradesh, Gujarat, Haryana, Karnataka, Kerala, Maharashtra, Meghalaya, Rajasthan	Andhra Pradesh, Goa, Gujarat, Karnataka, Kerala, Maharashtra, Meghalaya, Rajasthan, Sikkim, Tamil Nadu, Tripura, A&N Islands	Andhra Pradesh, Goa, Gujarat, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram, Nagaland, Orissa, Rajasthan, Sikkim, Tamil Nadu, Tripura, **West Bengal**, A&N Islands
Non availability of data / No reported cases	Chattisgarh, Jharkhand, Uttaranchal, A&N Islands, Chandigarh, D&NH, Daman & Diu, Lakshadweep, Pondicherry	Chattisgarh, Jharkhand, Uttaranchal, Chandigarh, Lakshadweep	Chandigarh, Lakshadweep

While formulating the RI for the states, area under foodgrains has been scaled with respect to gross cropped area. Goa, Madhya Pradesh, Mizoram, Nagaland, Orissa, Sikkim, Tamil Nadu and **West Bengal** have gone down in status between 1991 and 2000. Gross cropped area in Goa had increased substantially between 1991 and 1996 but not the area under foodgrains and hence it slipped to a lower status. The state of Chattisgarh has been formed from the state of Madhya Pradesh in 2000 and the area under foodgrains for the latter decreased considerably. This may have been the reason for its decrease in status. The areas under foodgrains have actually decreased for the states of Mizoram, Orissa, Sikkim, Tamil Nadu and **West Bengal** and hence these states have gone down in status. For Nagaland, the area under foodgrain has increased in the period under consideration, but by a much lesser magnitude than the gross cropped area. Hence it has fallen in status. Haryana had improved its status in the mid nineties but could not sustain it because the gross cropped area in the state increased by a much greater magnitude in the late nineties than the area under foodgrains.

Table 16: Gross Cropped Area

Sustainability Status	1990	1995	2000
Positive	Bihar, Gujarat, Haryana, Karnataka, Kerala, Maharashtra, Punjab, Rajasthan, Uttar Pradesh, West Bengal, Lakshadweep, Pondicherry	Bihar, Haryana, Karnataka, Kerala, Maharashtra, Punjab, Rajasthan, Uttar Pradesh, West Bengal, Lakshadweep, Pondicherry	Bihar, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Uttar Pradesh, **West Bengal**, D&NH, Lakshadweep, Pondicherry
Exact	India	India, Madhya Pradesh	India
Negative	Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Himachal Pradesh, J&K, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tamil Nadu, Tripura, A&N Islands, Chandigarh, D&NH, Daman & Diu, Delhi	Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Gujarat, Himachal Pradesh, J&K, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tamil Nadu, Tripura, A&N Islands, Chandigarh, D&NH, Daman & Diu, Delhi	Andhra Pradesh, Arunachal Pradesh, Assam, Chattisgarh, Goa, Gujarat, Himachal Pradesh, J&K, Jharkhand, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tamil Nadu, Tripura, Uttaranchal, A&N Islands, Chandigarh, Daman & Diu, Delhi
Non availability of data / No reported cases	Chattisgarh, Jharkhand, Uttaranchal	Chattisgarh, Jharkhand, Uttaranchal	

Gross cropped area has been scaled with respect to total geographical area while calculating RI. Gross cropped area in Gujarat has remained more or less the same in the decade under consideration whereas that of most of the other states in the positive sustainability status category has increased. Hence Gujarat has slipped down to a lower status. Madhya Pradesh, on the other hand, has bettered its status gradually in the nineties. This may be because gross cropped area in the state had increased in the mid nineties. Though there was a considerable decrease in gross cropped area in the state in 2000, the geographical area of the state has also decreased significantly after Chattisgarh was carved out of it. These factors may have helped it to improve its status.

Table 17: Gross Irrigated Area

Sustainability Status	1990	1996	2000
Positive	Andhra Pradesh, Haryana, Manipur, Meghalaya, J&K, Punjab, Tamil Nadu, Uttar Pradesh, West Bengal, Chandigarh, Delhi, Lakshadweep, Pondicherry	Andhra Pradesh, Bihar, Haryana, J&K, Punjab, Tamil Nadu, Uttar Pradesh, Chandigarh, Delhi, Pondicherry	Andhra Pradesh, Bihar, Haryana, J&K, Punjab, Tamil Nadu, Uttar Pradesh, Uttaranchal, Chandigarh, Delhi, Pondicherry
Exact	India, Bihar	India	India
Negative	Arunachal Pradesh, Assam, Goa, Gujarat, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Mizoram, Nagaland, Orissa, Rajasthan, Sikkim, Tripura, D&NH	Arunachal Pradesh, Assam, Goa, Gujarat, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Rajasthan, Sikkim, Tripura, West Bengal, D&NH, Daman & Diu	Arunachal Pradesh, Assam, Chattisgarh, Goa, Gujarat, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Rajasthan, Sikkim, Tripura, **West Bengal**, D&NH, Daman & Diu, Lakshadweep
Non availability of data / No reported cases	Chattisgarh, Jharkhand, Uttaranchal, A&N Islands, Daman & Diu	Chattisgarh, Jharkhand, Uttaranchal, A&N Islands, Lakshadweep	A&N Islands

Gross irrigated area has been scaled with respect to gross cropped area while calculating the RI. Manipur, Meghalaya, **West Bengal** and Lakshadweep have gone down in status in the nineties. This is because the gross irrigated areas have gone down in all these states. The same in Bihar had increased significantly in the mid nineties, thus helping the state to increase its status.

Consumption of chemical fertilizer and use of pesticide (Table 17 and 18 respectively) have been scaled with respect to gross cropped area.

Table 18: Chemical Fertilizer Consumption

Sustainability Status	1990	1996	2001
Positive	Assam, Gujarat, Himachal Pradesh, J&K, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Nagaland, Orissa, Rajasthan, Tripura	Arunachal Pradesh, Assam, Goa, Gujarat, Himachal Pradesh, J&K, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Nagaland, Orissa, Rajasthan, Sikkim, Tripura	Arunachal Pradesh, Assam, Chattisgarh, Goa, Gujarat, Himachal Pradesh, J&K, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram, Nagaland, Orissa, Rajasthan, Sikkim, Tripura, Delhi
Exact	India, Bihar, Karnataka	India	India
Negative	Andhra Pradesh, Haryana, Kerala, Mizoram, Punjab, Tamil Nadu, Uttar Pradesh, West Bengal	Andhra Pradesh, Bihar, Haryana, Punjab, Tamil Nadu, Uttar Pradesh, West Bengal, Delhi	Andhra Pradesh, Bihar, Haryana, Karnataka, Manipur, Punjab, Tamil Nadu, Uttar Pradesh, Uttaranchal, **West Bengal**
Non availability of data / No reported cases	Arunachal Pradesh, Chattisgarh, Goa, Jharkhand, Sikkim, Uttaranchal, A&N Islands, Chandigarh, D&NH, Daman & Diu, Delhi,	Chattisgarh, Jharkhand, Uttaranchal, A&N Islands, Chandigarh, D&NH, Daman & Diu, Lakshadweep, Pondicherry /	A&N Islands, Chandigarh, D&NH, Daman & Diu, Lakshadweep, Pondicherry

	Lakshadweep, Pondicherry	Mizoram	

Consumption of fertilizer has increased for Manipur over the nineties and hence its status has decreased. Fertilizer consumption of Bihar has not decreased significantly in the decade under consideration and hence it has gone down in status. For Karnataka, fertilizer consumption had decreased marginally in the mid nineties and its status had gone up. But due to a rapid increase in consumption of fertilizer in late nineties, Karnataka's status has slipped down.

Table 19: Use of Pesticides

Sustainability Status	1992	1996	2001
Positive	Arunachal Pradesh, Assam, Bihar, Goa, Himachal Pradesh, J&K, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Rajasthan, Sikkim, Tripura, Uttar Pradesh, D&NH, Daman & Diu	Arunachal Pradesh, Assam, Bihar, Goa, Himachal Pradesh, J&K, Karnataka, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Rajasthan, Sikkim, Tripura, Uttar Pradesh, A&N Islands, D&NH, Daman & Diu, Lakshadweep	Arunachal Pradesh, Assam, Bihar, Goa, J&K, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Rajasthan, Sikkim, Tripura, Uttaranchal, A&N Islands, D&NH
Exact	India	India, Tamil Nadu	India
Negative	Andhra Pradesh, Gujarat, Haryana, Punjab, Tamil Nadu, West Bengal, A&N Islands, Chandigarh, Delhi, Lakshadweep, Pondicherry	Andhra Pradesh, Gujarat, Haryana, Kerala, Punjab, West Bengal, Chandigarh, Delhi, Pondicherry	Andhra Pradesh, Gujarat Haryana, Himachal Pradesh, Kerala, Punjab, Tamil Nadu, Uttar Pradesh, **West Bengal**, Chandigarh, Daman & Diu, Delhi, Lakshadweep, Pondicherry
Non availability of	Chattisgarh,	Chattisgarh,	Chattisgarh

data / No reported cases	Jharkhand, Uttaranchal	Jharkhand, Uttaranchal	

Kerala could not maintain its position in the topmost status and has dropped down to the lowest one since the mid nineties. It had increased its consumption of pesticides by a large amount in between 1992 and 1995. Himachal Pradesh and Uttar Pradesh did not reduce their consumption of pesticide significantly and hence dropped down in status. Tamil Nadu had reduced its consumption of pesticide by a substantial margin in the mid nineties and hence its status had improved. But it could not maintain its rate of reduction in consumption of pesticide and hence slipped down in status in 2001. Lakshadweep's story has been similar in the same period. Andaman & Nicobar Islands however has managed to reduce its consumption of pesticide consistently in the decade under consideration and hence has improved it status.

Table 20: Forest Area

Sustainability Status	1991	1995	2001
Positive	Arunachal Pradesh, Assam, Goa, Himachal Pradesh, Kerala, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tripura, A&N Islands, D&NH	Arunachal Pradesh, Assam, Goa, Himachal Pradesh, Kerala, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tripura, A&N Islands, D&NH	Arunachal Pradesh, Assam, Chattisgarh, Goa, Himachal Pradesh, Jharkhand, Kerala, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tripura, Uttaranchal, A&N Islands, D&NH, Lakshadweep
Exact	India	India	India
Negative	Andhra Pradesh, Bihar, Gujarat, Haryana, J&K, Karnataka, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, Chandigarh, Delhi	Andhra Pradesh, Bihar, Gujarat, Haryana, J&K, Karnataka, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, Chandigarh, Delhi	Andhra Pradesh, Bihar, Gujarat, Haryana, J&K, Karnataka, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, **West Bengal,** Chandigarh,

			Daman & Diu,Delhi, Pondicherry
Non availability of data / No reported cases	Chattisgarh, Jharkhand, Uttaranchal / Daman & Diu, Lakshadweep, Pondicherry	Chattisgarh, Jharkhand, Uttaranchal / Daman & Diu, Lakshadweep, Pondicherry	

Forest area has been scaled with respect to geographical area of the respective states and union territories. Surprisingly no state or union territory has changed its status in the decade under consideration.

Table 21: Protected Areas and Wetlands

Sustainability Status	Protected Areas 2000	Wetlands 2000
Positive	Andhra Pradesh, Arunachal Pradesh, Bihar, Goa, Gujarat, Himachal Pradesh, J&K, Kerala, Madhya Pradesh, Maharashtra, Orissa, Sikkim, Tripura, Uttar Pradesh, A&N Islands, Chandigarh	Andhra Pradesh, Bihar, Goa, Gujarat, Karnataka, Kerala, Orissa, Tamil Nadu, West Bengal, Pondicherry
Exact	India	India
Negative	Assam, Haryana, Karnataka, Manipur, Meghalaya, Mizoram, Nagaland, Punjab, Rajasthan, Tamil Nadu, West Bengal, Daman & Diu, Delhi	Arunachal Pradesh, Assam, Haryana, Himachal Pradesh, J&K, Madhya Pradesh, Maharashtra, Manipur, Nagaland, Punjab, Rajasthan, Sikkim, Tripura, Uttar Pradesh,
Non availability of data / No reported cases	Chattisgarh, Jharkhand, Uttaranchal, D&NH, Lakshadweep, Pondicherry	Chattisgarh, Jharkhand, Meghalaya, Mizoram, Uttaranchal, A&N Islands, Chandigarh, D&NH, Daman & Diu, Delhi, Lakshadweep

Inter temporal comparisons between the states and union territories have not been possible because data for protected areas and wetlands are available only for the year 2000.

Table 22: Air Pollutants (SPM, RSPM, Oxides of nitrogen, Sulphur dioxide)

Sustainability Status	2001
Positive	Gujarat, Karnataka, Punjab, Tamil Nadu, **West Bengal**, Delhi
Exact	India
Negative	Andhra Pradesh, Bihar, Haryana, Kerala, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh
Non availability of data / No reported cases	Arunachal Pradesh, Assam, Chattisgarh, Goa, Himachal Pradesh, J&K, Jharkhand, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tripura, Uttaranchal, Others

We have considered the air quality status of 'million plus' cities and scaled the same against total populations. Table 22 shows the list of cities of the respective states, whose data are available:

Table 23: List of States / Union Territories and Cities

States / Union territories	Cities
Andhra Pradesh	Hyderabad and Vishakhapatnam
Bihar	Patna
Delhi	Delhi
Gujarat	Ahmedabad and Vadodara
Haryana	Faridabad
Karnataka	Bangalore
Kerala	Kochi
Madhya Pradesh	Bhopal, Indore and Jabalpur
Maharashtra	Mumbai, Nagpur, Nasik and Pune
Punjab	Ludhiana
Rajasthan Tamil Nadu	Jaipur Chennai, Madurai
Uttar Pradesh	Agra, Kanpur, Lucknow, Varanasi
West Bengal	Kolkata

In Tables 24 to 28 we evaluate the positions of the states and union territories with respect to diseases. We have considered vector borne diseases like malaria and dengue, water borne disease like diarrhoea and diseases like asthma and whooping cough that can be related to air pollution. The diseases have been scaled with respect to the total populations while calculating the respective RIs.

Table 24: Reported cases of Asthma

Sustainability Status	1999
Positive	Bihar, Goa, Gujarat, Haryana, Himachal Pradesh, J&K, Karnataka, Madhya Pradesh, Manipur, Mizoram, Punjab, Tamil Nadu, Uttar Pradesh, Delhi
Exact	India
Negative	Andhra Pradesh, Arunachal Pradesh, Assam, Kerala, Maharashtra, Meghalaya, Nagaland, Orissa, Rajasthan, Sikkim, **West Bengal**
Non availability of data / No reported cases	Chattisgarh, Jharkhand, Tripura, Uttaranchal, A&N Islands, Chandigarh, D&NH, Daman &Diu, Lakshadweep, Pondicherry

Table 25: Reported cases of Malaria

Sustainability Status	2001
Positive	Andhra Pradesh, Bihar, Gujarat, Haryana, Himachal Pradesh, J&K, Kerala, Maharashtra, Manipur, Nagaland, Punjab, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh, Uttaranchal, **West Bengal**, Chandigarh, Daman &Diu, Delhi, Lakshadweep, Pondicherry
Exact	India
Negative	Arunachal Pradesh, Assam, Chattisgarh, Goa, Jharkhand, Karnataka, Madhya Pradesh, Meghalaya, Mizoram, Orissa, Tripura, A&N Islands, D&NH
Non availability of data / No reported cases	

Table 26: Reported cases of Diarrhoea

Sustainability Status	2000
Positive	Goa, Gujarat, Haryana, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Nagaland, Punjab, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh, Chandigarh, Daman &Diu, Delhi, Lakshadweep
Exact	India
Negative	Andhra Pradesh, Himachal Pradesh, J&K, Karnataka, Kerala, Meghalaya, Orissa, Sikkim, West Bengal, A&N Islands, Pondicherry
Non availability of data / No reported cases	Arunachal Pradesh, Assam, Bihar, Chattisgarh, Jharkhand, Uttaranchal, D&NH

Table 27: Reported cases of Dengue

Sustainability Status	2000
Positive	Andhra Pradesh, Gujarat, Haryana
Exact	India

Negative	Karnataka, Maharashtra, Punjab, Tamil Nadu, Delhi
Non availability of data / No reported cases	Arunachal Pradesh, Assam, Chattisgarh, Himachal Pradesh, J&K, Jharkhand, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Uttaranchal**, West Bengal**, A&N Islands, D&NH,Daman &Diu, Lakshadweep / Bihar, Goa, Kerala, Orissa, Rajasthan, Uttar Pradesh, Chandigarh, Pondicherry

Table 28: Reported cases of Whooping Cough

Sustainability Status	2001
Positive	Goa, Gujarat, Haryana, Kerala, Maharashtra, Mizoram, Orissa, Punjab, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh, A&N Islands, , Daman &Diu, Delhi, Pondicherry
Exact	India
Negative	Andhra Pradesh, J&K, Karnataka, Madhya Pradesh, Manipur, Meghalaya, Nagaland, Sikkim**, West Bengal**
Non availability of data / No reported cases	Arunachal Pradesh, Assam, Bihar, Chattisgarh, Jharkhand, Uttaranchal, D&NH / Himachal Pradesh, Chandigarh, Daman &Diu, Lakshadweep

Table 21 shows that the states like Andhra Pradesh, Kerala, Madhya Pradesh and Rajasthan, along with some others belong to the negative sustainability status category with respect to air quality. It is interesting to see that these states fall in the negative sustainability status category with respect to the diseases like either asthma or whooping cough or both, which can be related, as has already been mentioned, to air pollution. So if the air quality in the major cities of these states (see Table 22) can be improved, perhaps the incidence of asthma and whooping cough can be lowered.

Also, Table 5 shows that states like Jammu & Kashmir, Kerala, Meghalaya, Orissa and Sikkim, along with some others belong to the negative sustainability status category with respect to population with safe drinking water. This is consistent with the fact that these states also belong to the negative sustainability status category in Table 25, which shows the status of the states and union territories with respect to diarrhoea. So an improvement in the supply of safe drinking water in these states will perhaps help in lowering of the incidence of diarrhoea.

VI.I.III Economic indicators

Tables 29 – 32 show the status of states and union territories with respect to economic indicators like GDP, fiscal deficit, consumption of electricity and investments. We have not considered investments in industry, agriculture and education separately, but have added the respective values for each state to assess their status in achieving sustainability. Also, while calculating the respective RIs, the indicators have been scaled with respect to the total population of the states and union territories.

Table 29: Gross Domestic Product

Sustainability Status	2001
Positive	Andhra Pradesh, Maharashtra, Tamil Nadu,Uttar Pradesh, **West Bengal**
Exact	India, Gujarat
Negative	Arunachal Pradesh, Assam, Bihar, Chattisgarh, Goa, Haryana, Himachal Pradesh, J&K, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Manipur, Meghalaya, Nagaland, Orissa, Punjab, Rajasthan, Sikkim, Tripura, Uttaranchal, A&N Islands, Chandigarh, Delhi, Pondicherry
Non availability of data / No reported cases	Mizoram, D&NH, Daman &Diu, Lakshadweep

Table 30: Fiscal deficit

Sustainability Status	2001
Positive	Assam, Bihar, Chattisgarh, J&K, Karnataka, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh
Exact	India
Negative	Andhra Pradesh, Arunachal Pradesh, Goa, Gujarat, Haryana, Himachal Pradesh, Kerala, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Punjab, Sikkim, Tamil Nadu, Tripura**,** **West Bengal**, Delhi
Non availability of data / No reported cases	Jharkhand, Uttaranchal, A&N Islands, Chandigarh, D&NH, Daman &Diu, Lakshadweep, Pondicherry

Table 31: Consumption of Electricity

Sustainability Status	2001
Positive	Andhra Pradesh, Goa, Gujarat, Haryana, Karnataka, Maharashtra, Punjab, Tamil Nadu, Chandigarh, D&NH,

	Daman &Diu, Delhi, Pondicherry
Exact	India
Negative	Arunachal Pradesh, Assam, Bihar, Himachal Pradesh, J&K, Kerala, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Rajasthan, Sikkim, Tripura, Uttar Pradesh, **West Bengal**, A&N Islands, Lakshadweep
Non availability of data / No reported cases	Chattisgarh, Jharkhand, Uttaranchal

Table 32: Investments (Industries, Agriculture, Education)

Sustainability Status	2001
Positive	Goa, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Maharashtra, Punjab, Tamil Nadu, D&NH, Daman &Diu, Pondicherry
Exact	India
Negative	Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chattisgarh, J&K, Kerala, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Rajasthan, Sikkim, Tripura, Uttar Pradesh, Uttaranchal, **West Bengal**, A&N Islands, Chandigarh, Delhi, Lakshadweep
Non availability of data / No reported cases	

We see that the states and union territories of Arunachal Pradesh, Assam, Bihar, Himachal Pradesh, Jammu & Kashmir, Kerala, Madhya Pradesh, Manipur, Meghalaya, Nagaland, Orissa, Rajasthan, Sikkim, Tripura, Andaman & Nicobar Islands and Delhi have belonged to the negative sustainability status category with respect to most of the economic indicators and this is also reflected in their poor rankings based on the CENI as shown in Table 33. So it is of immense importance that good economic policies should be designed for economic welfare of these states.

VII. Estimating Semi Composite Indices using RRIs and relative Ranks of States and Union Territories

In Section VI we show the sustainability status of the states and union territories separately with respect to the individual indicators of sustainability. Based on (28 x 35) RI values we can categorize the states and union territories through summary presentation in Tables 5 to 32. Now we proceed to try and rank the states separately in the social, environmental and economic categories for the year 2001 to derive implication of the analysis. If the preceding section of our analysis gives us an idea about the sustainability status of the states and union territories, this section helps us to have an exact idea regarding the positions of the states and union territories on the path of sustainable development. Table 33 shows the ranks of the states and union territories based on the semi composite indices.

Table 33: Ranks for 2001 based on Semi Composite Indices

States and Union Territories	Ranks		
	Composite Social Index (CSCI)	Composite Environmental Index (CENI)	Composite Economic Index (CECI)
Andhra Pradesh	13	30	10
Arunachal Pradesh	28	33	35
Assam	16	17	27
Bihar	21	7	25
Chattisgarh	30	31	13
Goa	35	1	7
Gujarat	6	3	4
Haryana	24	22	8
Himachal Pradesh	15	26	29
Jammu & Kashmir	14	25	24
Jharkhand	9	18	18
Karnataka	7	28	9
Kerala	8	8	22
Madhya Pradesh	33	21	17
Maharashtra	12	12	5
Manipur	17	13	31
Meghalaya	26	32	30
Mizoram	18	14	32
Nagaland	22	35	34
Orissa	29	27	20
Punjab	2	24	11
Rajasthan	27	19	16
Sikkim	23	15	28
Tamil Nadu	5	11	6
Tripura	20	9	33
Uttar Pradesh	34	16	14
Uttaranchal	10	6	23
West Bengal	1	10	21
Andaman & Nicobar Islands	11	2	26
Chandigarh	31	5	12

Dadra & Nagar Haveli	19	23	1
Daman & Diu	3	20	2
Delhi	32	34	15
Lakshadweep	25	4	19
Pondicherry	4	29	3

Note: Lower is the magnitude of the rank; better is the performance of the state or union territory

When we go through the above table, quite a few states draw our attention because of their anomalous performances in the three categories. Let us examine these states individually. Andhra Pradesh has performed moderately in the social and economic categories but quite poorly in the environmental one. This is because of its relatively high consumption of chemical fertilizers coupled with relatively high incidences of asthma, diarrhoea, and whooping cough. Bihar in spite of not having performed well in the social and economic categories has surprisingly done very well in the environmental category. Relatively high values for the indicators of gross cropped area, high prevalence of wetlands and low incidence of malaria has made up for the high pollution in its million plus cities. Also, the separation of the state of Jharkhand has resulted in a decrease of Bihar's geographical area by almost 50%, whereas gross cropped area of the state has diminished by a small amount. Hence the value of representation index of gross cropped area has come out to be a moderately high positive one, thus helping the state to grab a high rank in the environmental category. Goa has done exceedingly well in the environmental and economic categories but has got the last rank in the social category. The reason for this can be attributed to the very high relative crimes against women and children. So this is a matter of serious concern for Goa. Haryana has done quite well in the economic front because of moderately high relative value of investments in the state. Karnataka has bagged positions in the top ten states in the social and economic categories but has done very poorly in the environmental one. This is because of very high relative prevalence rates of diarrheoa and dengue. Kerala, on the other hand, has done quite well in the social and environmental categories, but pretty poorly in the economic front. This is because of relatively low GDP and high fiscal deficit. Maharashtra has fared pretty well in the environmental and economic fronts, but not so well in the social category. The reason is that the relative value of crime against children is quite high in the state. Punjab has done very well in the social category and not so badly in the economic front, but has got a much lower position in the environmental category. This is because of relatively high consumption of fertilizers and pesticides, low forest cover and high incidence of dengue cases in the state. Tripura has performed very well in the environmental category because of relatively low consumption of fertilizers and pesticides and there is a high forest cover in the state. Uttaranchal has done very well in the social and environmental categories but quite poorly in the economic one because of low relative values of electricity consumption and investments. **West Bengal** has performed well in the social category and bagged the first place mainly due lower relative crime rates against women and children. In the environmental category, in spite of presence of relatively high cropped areas and wetlands, the relatively high incidence of diarrhoea has pushed the state back to the tenth place. But in the economic category, the position has been a low twenty first. This is because of low relative values of electricity consumption and investments coupled with a relatively high fiscal deficit. Andaman & Nicobar Islands has performed poorly in the economic front because of a low relative value of GDP along with low electricity consumption and investments. High forest cover and protected area has helped this union territory to bag the third rank in the environmental category. Chandigarh, though having done well in the environmental and economic categories, has fared very poorly in the social one because of relatively very high crime rates against children. Dadra & Nagar Haveli has got the first position in the economic category, but has done pretty poorly in the environmental one. This is because of relatively high incidence of malaria while data for the most of the other indicators are not available. Delhi, the national capital, has performed extraordinarily poorly in the social and environmental categories. The poor performance in the social category can be attributed to very high relative crime rates against women and children, while that in the environmental one is due to very high relative incidence of dengue along with high consumption of pesticides. Lastly, Pondicherry, which has performed so well in the social and economic categories, has done poorly in the environmental one. This is because of high relative incidence of diarrheoa and high consumption of pesticide.

VIII. CSI estimates and Ranks of the States and Union Territories

Detailed CSI estimates are given in the Annexure. We present here the ranks of the states and union territories based on the CSI for the year 2001 for facilitating the analysis.

Table 34: Ranks for 2001 based on CSI

States and Union Territories	**Ranks**	**CSI**
Dadra & Nagar Haveli	1	4195
Daman & Diu Pradesh	2	4106
Gujarat	3	785
Tamil Nadu	4	485
Maharashtra	5	438
Andaman & Nicobar Islands	6	414
West Bengal	7	315
Uttaranchal	8	237
Lakshadweep	9	218
Kerala	10	189
Pondicherry	11	150
Bihar	12	90
Jharkhand	13	5
Chandigarh	14	-23
Punjab	15	-64
Tripura	16	-112
Assam	17	-142
Rajasthan	18	-174
Manipur	19	-183
Mizoram	20	-201
Sikkim	21	-204
Haryana	22	-216
Karnataka	23	-277
Andhra Pradesh	24	-433
Jammu & Kashmir	25	-460
Uttar Pradesh	26	-628
Himachal Pradesh	27	-654
Madhya Pradesh	28	-667
Orissa	29	-674
Chattisgarh	30	-748
Meghalaya	31	-1323
Arunachal Pradesh	32	-2108
Goa	33	-2346
Delhi	34	-2356
Nagaland	35	-4519

Note: Lower is the magnitude of the rank; better is the performance of the State or Union Territory

The ranks shown in table 34 (arranged in ascending order and magnitude) give us a clear idea about the positions of the states and union territories on the path to achieving sustainability. The important thing that is to be kept in mind is that lower is the magnitude of the rank of a state or a union territory, better is its status in achieving sustainability and vice versa. So the state or the union territory that is ranked 1, leads the way. The states and union territories ranked between 1 and 13 have positive CSI values while all others have negative values. So this helps us in understanding which states and union territories are in dire needs of good policies which will help them in achieving sustainability. But this does not mean that the states or union territories which have negative values of composite sustainability index are the only ones which need policy interventions. There are issues where even the better performing states and union territories have not done well. All the issues of concern for the states and union territories have been dealt with in Section IX.

In Figure 2 we have shown the CSI values of the states and union territories for the year 2001. The CSI values are plotted along the vertical axis while the states and union territories along the horizontal axis.

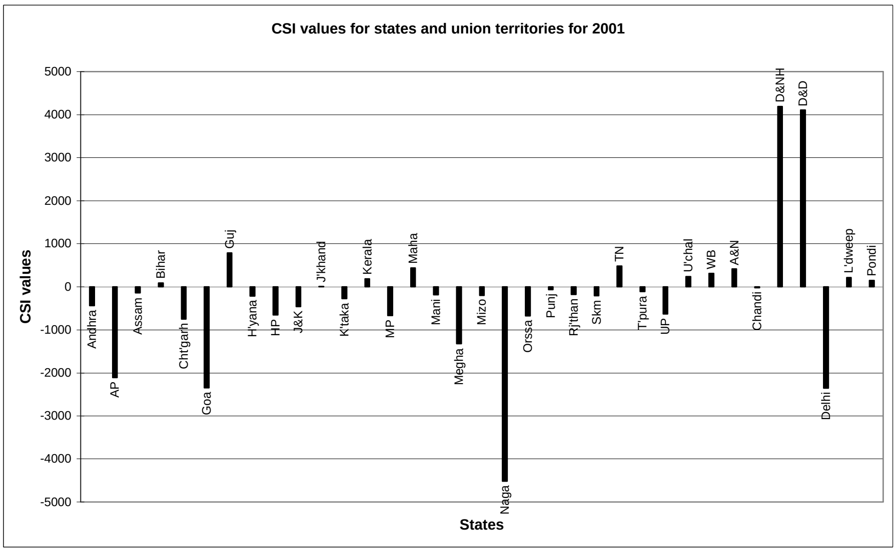


Fig 2: CSI values for the States and Union Territories of India

IX. Issues of concern and policy recommendations to mainstream sustainable development

Based on detailed component analysis we have prepared a list of issues of concern for each state and union territory. Table 35 shows the list. We have divided the states and union territories into two groups. In Group I we have shown those states and union territories which have negative CSI values (see Table 34) and hence can be considered to be away from the sustainable development pathway. In Group II we have shown the remaining states and union territories which have positive CSI values (see Table 34) and hence can be considered to be on the sustainable development pathway. States and union territories with ascending values of CSI have been arranged in sequence. We have defined an issue of concern as that where a state or a union territory has been performing poorly and as a result, deviating away from the path of achieving sustainability judged by a movement below the benchmark. Hence it is of utmost importance that policies should be designed keeping these issues of concern in mind. This will help in bringing the states and union territories back on the path of achieving sustainability. While preparing the list of issues of concern, we had to go through the RRI of each state and union territory for all the individual indicators. Priorities of the issues of concern have been decided for each state and union territory based on the values of the relative representation indices. For any state, the sustainability indicator having the minimum RRI value has been given the highest priority for that state and so on towards its achievement of sustainable development.

Table 35: Issues of Concern

States and Union Territories	Issues of concern according to priority		
	1	2	3
Group I – States and Union Territories with negative values of CSI			
Nagaland	Whooping cough and asthma	Fiscal deficit	Wetlands
Delhi	Dengue	Crime against children and women	Pesticide and fertilizer consumption
Goa	Crime against women and children	Fiscal deficit	Malaria
Arunachal Pradesh	Malaria	Fiscal deficit	Gross cropped and irrigated area
Meghalaya	Diseases like whooping cough, diarrhoea, malaria and asthma	Investment	Safe drinking water
Chattisgarh	Malaria	Crime against children	Gross irrigated area
Orissa	Malaria and diarrhoea	Population BPL	Infant Mortality Rate
Madhya Pradesh	Crime against women and children	Whooping cough and malaria	Air pollution
Himachal Pradesh	Diarrhoea	Fiscal deficit	Gross cropped and irrigated area
Uttar Pradesh	Polio	Air pollution	Crime against children
Jammu & Kashmir	Diarrhoea	Gross cropped area	Crime against women
Andhra Pradesh	Diseases, especially whooping cough, diarrhoea and asthma	Fertilizer and pesticide consumption	Air pollution

Karnataka	Diseases especially dengue and diarrhoea	Gross irrigated area	Protected area
Haryana	Air pollution	Pesticide consumption	Wetlands and protected area
Sikkim	Whooping cough, asthma and diarrhoea	Gross cropped and irrigated area	Investment
Mizoram	Malaria	Fiscal deficit	Gross cropped and irrigated area
Manipur	Whooping cough	Investment	Electricity consumption
Rajasthan	Air pollution	Crime against women	Forest cover and wetlands
Assam	Electricity consumption	Investment	Gross irrigated area
Tripura	Malaria	Investment	Electricity consumption
Punjab	Dengue	Consumption of pesticides and fertilizers	Fiscal deficit
Chandigarh	Crime against children and women	Consumption of pesticides	Forest cover
Group II – States and Union Territories with positive values of CSI			
Jharkhand	Malaria	Gross cropped and irrigated area	Safe drinking water
Bihar	Air pollution	Investment	Forest cover
Pondicherry	Consumption of pesticide	Diarrhoea	Forest cover
Kerala	Air pollution	Diseases especially diarrhoea and asthma	Safe drinking water
Lakshadweep	Consumption of pesticide	Safe drinking water	Crime against children
West Bengal	Diarrhoea	Fertilizer and pesticide consumption	Fiscal deficit
Andaman & Nicobar Islands	Diarrhoea and malaria	Gross cropped area	Electricity consumption
Maharashtra	Crime against children	Air pollution	Gross irrigated area
Tamil Nadu	Dengue	Fertilizer consumption	Protected area
Gujarat	Fiscal deficit	Forest cover	Area under foodgrains
Uttaranchal	Gross cropped area	Investment	Polio

Daman & Diu	Consumption of pesticide	Forest Cover	Protected area
Dadra & Nagar Haveli	Malaria	Gross irrigated area	Crude Birth Rate

Table 35 can be of immense help to policy makers when they try to prioritize development action, which will help the states and union territories to achieve sustainability. For example, for the state of West Bengal, the most important issues to be addressed are diarrhoea, fertilizer and pesticide consumption and fiscal deficit. So, maximum efforts should be made to reduce the cases of diarrhoea, consumption of fertilizer and pesticide, and finally fiscal deficit.

A detailed study of Table 35 reveals the fact that as many as twenty eight states and union territories have an environmental issue as the primary issue of concern. Similarly five states and union territories have a social issue and two states have an economic issue as the primary issues of concern respectively. Also the importance of environmental issues in policy formulation lies in the fact that every state and union territory has at least one environmental issue as an issue of concern, if not always the primary one.

The other thing that can be observed from Table 35 is that there are twenty eight different issues of concern for the states and union territories. In Table 36 we represent these issues of concern along with the respective number of states and union territories having those issues as issues of concern.

Table 36: Issues of concern and number of States and UTs

Issues of Concern	Number of States and UTs
Social issues	**16**
Crime against Children	8
Crime against Women	6
Population with access to Safe Drinking Water	4
Reported cases of Polio	2
Population below Poverty Line	1
Infant Mortality Rate	1
Crude Birth Rate	1

Environmental Issues	35
Reported cases of malaria	11
Reported cases of diarrhoea	11
Gross irrigated area	10
Consumption of pesticides	9
Concentration of air pollutants in million plus cities	8
Gross cropped area	8
Forest area	6
Reported cases of whooping cough	6
Consumption of fertilizers	5
Reported cases of asthma	5
Protected area	4
Reported cases of dengue	4
Wetlands	3
Area under foodgrains	1
Economic	**16**
Fiscal deficit	8
Investments (Industry, agriculture, education)	7
Consumption of electricity	4

The importance of environmental issues is once again emphasized by the fact that all the thirty five states and union territories have these as issues of concern. On the other hand, the number of states and union territories having social or economic issues as issues of concern is sixteen in each case. The names of the respective states and union territories corresponding to the issues of concern mentioned in Table 36 have been given in the annexure (see Table A1).

Among the social issues of concern, the ones that dominate are crimes against children and women.

Among the environmental issues of concern, the ones that figure the maximum number of times are reported cases of malaria and diarrhoea. If all the diseases like asthma, malaria, diarrhoea, dengue and whooping cough are clubbed together, then it can be seen that these diseases come up for thirty seven times in total as issues of concern. Agriculture, consisting of area under foodgrains, gross cropped and irrigated area and consumption of fertilizers and pesticides occur for thirty three times as issues of concern. So diseases are the most important issues of concern followed by agriculture in the environmental category.

Among the economic issues of concern, fiscal deficit closely followed by investments figure as the most serious issues of concern.

This analysis also helps us to identify the top four issues of concern for the states and union territories in India. This becomes important from the context of a policy maker who has, at his disposal, a limited amount of fund that he can allocate to address the issues of concern. Table 36 helps us to prioritize the issues of concern. The top four issues of concern are as follows:

i) reported cases of malaria and diarrhoea (each of these are issues of concern for eleven states and union territories)
ii) gross irrigated area (this is an issue of concern for ten states and union territories)
iii) consumption of pesticides (this is an issue of concern for nine states and union territories)
iv) crime against children, air pollution, gross cropped area and fiscal deficit (each of these are issues of concern for eight states and union territories).

Adequate policy intervention addressing these issues will help the states and union territories to move in the right direction on the sustainable development pathway.

Now, not all of these issues are subjects of the state list as defined in the Constitution of India. It can be mentioned here that the state governments have independent legislative jurisdiction over the subjects like agriculture and drinking water, which are included in the state list. Subjects like electricity, forest cover, protected area and population control, which are included in the concurrent list come under the joint legislative jurisdiction of the union and state governments. So the state governments can independently design policies for the issues included in the state list while for those included in the concurrent list, the union government will also have an important role to play in designing policies along with the state governments.

Lastly, it can be seen that there are a few issues of concern like the sex ratio and the crude birth rate over which the government does not have a direct control but can use policies to achieve behavioural change. What it can do is to influence the mind set of the people by creating awareness of population explosion and adverse sex ratios and thus help the states to achieve sustainability. For some of the issues like lowering the incidence of diseases and infant mortality rates, the government can provide better healthcare facilities and also educate the people more about how to take precautionary measures regarding the diseases, especially vector borne ones. Regarding a few other issues like the lowering fiscal deficits and crime rates, increasing investments and providing safe drinking water, the government can take more active measures to improve the situations. Thus it can be seen that the government will have to involve the local people more actively to solve some of the issues of concern. In fact, as has already been referred to in the introduction, addressing local issues through the involvement of the local people is one of the prerequisites of sustainable development.

We have tried to represent the issues of concern of the topmost priority for each state and union territory of India with the help of the following map of India.

Table A1: Issues of concern and States and UTs

Issues of Concern	Numbers of States and UTs	Names of States and Union Territories
Crime against Children	8	Delhi, Goa, Chattisgarh, MP, UP, Chandigarh, Lakshadweep, Maharashtra
Crime against Women	6	Delhi, Goa, MP, J&K, Rajasthan, Chandigarh
Population with access to Safe Drinking Water	4	Meghalaya, Jharkhand, Kerala, Lakshadweep
Reported cases of Polio	2	UP, Uttaranchal
Population below Poverty Line	1	Orissa
Infant Mortality Rate	1	Orissa

Crude Birth Rate	1	D&NH
Reported cases of malaria	11	Goa, Arunachal Pradesh, Meghalaya, Chattisgarh, Orissa, MP, Mizoram, Tripura, Jharkhand, A&N Islands, D&NH
Reported cases of diarrhoea	11	Meghalaya, Orissa, HP, J&K, Andhra Pradesh, Karnataka, Sikkim, Pondicherry, Kerala, WB, A&N Islands,
Gross irrigated area	10	Arunachal Pradesh, Chattisgarh, HP, Karnataka, Sikkim, Mizoram, Assam, Jharkhand, Maharashtra, D&NH
Consumption of pesticides	9	Delhi, Andhra Pradesh, Haryana, Punjab, Chandigarh, Pondicherry, Lakshadweep, WB, D&D
Concentration of air pollutants in million plus cities	8	MP, UP, Andhra Pradesh, Haryana, Rajasthan, Bihar, Kerala, Maharashtra
Gross cropped area	8	Arunachal Pradesh, HP, J&K, Sikkim, Mizoram, Jharkhand, A&N Islands, Uttaranchal
Forest area	6	Rajasthan, Chandigarh, Bihar, Pondicherry, Gujarat, D&D
Reported cases of whooping cough	6	Nagaland, Meghalaya, MP, Andhra Pradesh, Sikkim, Manipur
Consumption of fertilizers	5	Delhi, Andhra Pradesh, Punjab, WB, TN
Reported cases of asthma	5	Nagaland, Meghalaya, Andhra Pradesh, Sikkim, Kerala
Protected area	4	Karnataka, Haryana, TN, D&D
Reported cases of dengue	4	Delhi, Karnataka, Punjab, TN
Wetlands	3	Nagaland, Haryana, Rajasthan
Area under foodgrains	1	Gujarat
Fiscal deficit	8	Nagaland, Goa, Arunachal Pradesh, HP, Mizoram, Punjab, WB, Gujarat
Investments (Industry, agriculture, education)	7	Meghalaya, Sikkim, Manipur, Assam, Tripura, Bihar, Uttaranchal
Consumption of electricity	4	Manipur, Assam, Tripura, A&N Islands

Note: i) HP: Himachal Pradesh ii) J&K: Jammu & Kashmir, iii) MP: Madhya Pradesh, iv) UP: Uttar Pradesh,
v) WB: West Bengal, vi) A&N Islands: Andaman & Nicobar Islands, vii) D&D: Daman & Diu,
viii) D&NH: Dadra & Nagar Haveli ix) TN: Tamil Nadu

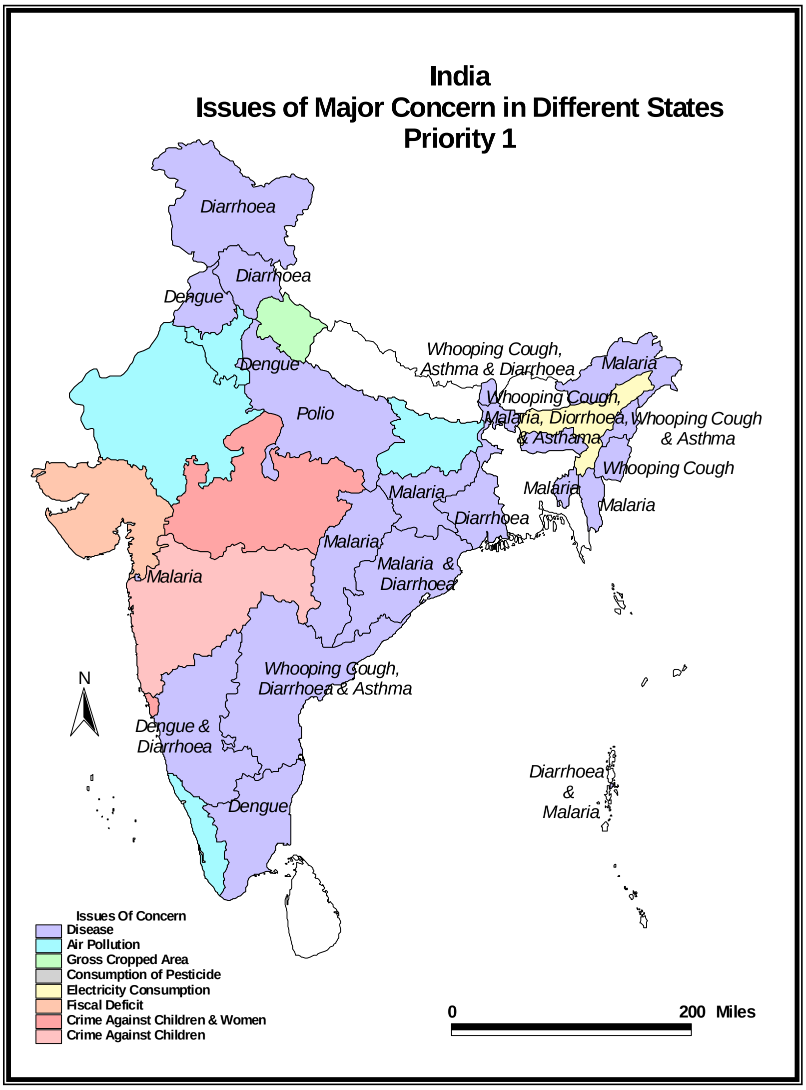


Fig 3: Map of India showing the issues of concern of prime priority for the States and Union territories

X. Switching between Sustainability Statuses on Development Pathway

As mentioned in Section V, besides cross-section comparison, inter temporal comparison in performance status can also be made through CSI. In this section we have calculated the ranks of the states and union territories both for 1991 and 2001. Detailed calculations are shown in the annexure (see Tables A34 through A38). The ranks for 2001 that have already been shown in Table 34 may be different from the ranks for 2001 shown in the Table 36. This is because previously we had used all the twenty eight indicators of sustainability to rank the states and union territories. But here we have used only thirteen of them to calculate the new CSI for 2001. This has been done because data for only these thirteen indicators are available for 1991. Hence the CSI for 1991 has been calculated using these thirteen indicators only. So to maintain comparability between 1991 and 2001 we have used these thirteen indicators only to calculate the CSI for both 1991 and 2001 to understand whether there is any switch in sustainable development pathway for the states and union territories. The indicators that have been used are as follows:

Social Indicators:

i) Percent of population below poverty line
ii) Population with access to safe drinking water
iii) Sex ratio
iv) Adult literacy rates
v) Infant mortality rate
vi) Crude birth rate
vii) Life expectancy

Environmental Indicators:

i) Area under foodgrains
ii) Gross cropped area
iii) Gross irrigated area
iv) Chemical fertilizer consumption
v) Use of pesticides
vi) Forest area

Table 37: Ranks for 1991 and 2001

States and Union Territories	Ranks	
	1991	2001
Group I - States and Union Territories who maintained positive sustainability status overtime		
Arunachal Pradesh	4	4
Assam	14	21
Bihar	20	23
Goa	10	1
Himachal Pradesh	11	16
Jammu & Kashmir	17	14
Kerala	13	11
Maharashtra	21	17
Manipur	2	7
Meghalaya	3	10
Mizoram	16	2
Nagaland	1	6
Punjab	6	18
Sikkim	12	12
Tripura	8	5
West Bengal	18	20
Andaman & Nicobar Islands	7	3
Lakshadweep	9	9
Group II - States and Union Territories who maintained negative sustainability status overtime		
Andhra Pradesh	31	33
Gujarat	28	32
Orissa	25	26
Rajasthan	26	30
Delhi	27	34
Pondicherry	32	35
Group III - States and Union Territories who switched sustainability status overtime		
Haryana	15	31
Madhya Pradesh	22	25
Chandigarh	5	27
Daman & Diu	19	29
Uttar Pradesh	23	28
Karnataka	24	19
Tamil Nadu	30	22
Dadra & Nagar Haveli	29	13
Group IV – New States which were created between 1991 and 2001		
Chattisgarh	-	15
Jharkhand	-	24
Uttaranchal	-	8

In Table 37, we have divided the states and union territories into four groups. Group I shows those states and union territories which had positive values of CSI for both of the years 1991 and 2001 and hence maintained positive sustainability status in the period under consideration. Group II shows those states and union territories which had negative values of CSI for both of the years 1991 and 2001 and hence maintained negative sustainability status in the period under consideration. Group III shows those states and union territories which switched sustainability status in the period under consideration. Some of these like Haryana, Madhya Pradesh, Uttar Pradesh, Chandigarh and Daman & Diu switched from positive to negative sustainability status while the others like Karnataka, Tamil Nadu and Dadra & Nagar Haveli switched from negative to positive sustainability status between 1991 and 2001.

In 1991, the first twenty-three ranked states and union territories were above the switch value of the CSI i.e. had positive values of the CSI and hence positive sustainability status, Similar was the situation in 2001. In Figure 3 we have illustrated the movement of the CSI values of the union territories of Chandigarh and Dadra & Nagar Haveli between 1991 and 2001. The CSI values of these two union territories have changed by a big margin in the period under consideration.

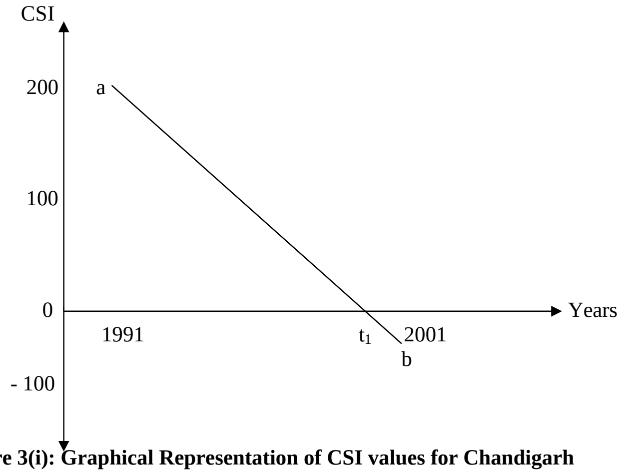


Figure 3(i): Graphical Representation of CSI values for Chandigarh

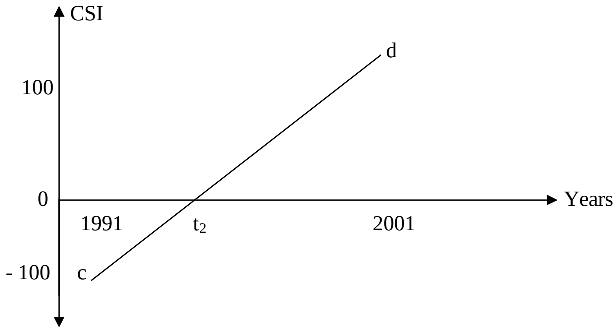


Figure 3(ii): Graphical Representation of CSI values for Dadra & Nagar Haveli

The line ‘ab’ in Fig 3(i) represents the graph of the CSI value of Chandigarh. The graph has a switch point at ‘t_1’. Hence (as also mentioned in Table 37), Chandigarh has switched from a positive to a negative sustainability status. This has happened mainly due to a decrease in the RI of gross irrigated area and an increase in the RI of pesticide consumption.

The line ‘cd’ in Fig 3(ii) represents the graph of the CSI value of Dadra & Nagar Haveli. This graph has a switch point at ‘t_2’. Hence (As also mentioned in Table 37) Dadra & Nagar Haveli has switched from a negative to a positive sustainability status. This has happened mainly due to an increase in the RI of gross irrigated area and a decrease in the RI of population below poverty line. The corresponding ranks of the two union territories for the years 1991 and 2001 have been shown in Table 37.

XI. Concluding Remarks

This chapter proposes a method for arriving at a ‘single index of sustainability’ namely the CSI and demonstrates how to apply it to assess the status of the states and union territories of India on the development pathway. This has helped us to identify the issues of concern of each state and union territory. The study has shown how through appropriate policy prioritization the states and union territories can mainstream environmental issues and follow the sustainable development pathway.

However it is quite evident from the current study that the areas of concern differ largely for the states and union territories. Unsustainability can result not only from environmental issue but from social and economic issues also. Hence a single policy for all of the states and union territories would not be the solution. Environmentally biased policies may also not be a solution towards achievement of sustainable development. Rather, judicious and different combinations of policies for different states could help them in moving closer to achieving sustainability by moving on or beyond the benchmark.

We find that CSI as a measure of sustainability status is sensitive to the components of the index. So as a future research agenda it will be useful to take up the issue of the possibility of identifying by some means the most important components as standard components across time and space to arrive at CSI. This report could have been more informative if we could have got all the data required to carry out such an exercise. But from a practical point of view, non-availability of data for different states for a large number of indicators acted as a major constraint. Given these limitations, this exercise can be regarded as a first and modest attempt to assess the positions of the states and union territories of India on the development pathway through construction and comparison of one single index of sustainability.

We tried to construct similar index for West Bengal for districts but paucity of data on environmental indicators is the major hurdle and shows what kind of data base creation is needed to follow three pillar approaches.

Chapter III

Water Account

Three pillar approach in Chapter II has shown that West Bengal has enough reasons to take care of its water resources. Water borne diseases is identified as major source of un-sustainability of its development pathway. It has already been recognized in UN system (UN 2006) that because of its critical and intimate relation with socio-economic development water resource management needs to be considered within an integrated approach. Following the various approaches suggested for integrated approach we present in this chapter the framework that we have followed to provide hydrological and economic information that is consistent with SEEAW (UN 2003, 2006). Although UN system has suggested a framework the availability of information and local specificities needs to be looked into carefully to understand how the water account can be constructed.

Some information as to which country has taken recourse to which form of accounting is available. We present the information in form of a table:

Countries	**Type of accounting**
France	Modeled all aspects of hydrological cycle and included extensive water quality account in addition to water quantity
Spain, Chile, Moldova	Adopted French approach but account were not extensive
Germany	Attempted on stock account only
Sweden, Denmark	NAMEA: Focusing on the use of water by economic activity and the cost of providing and treating this water. No stock account created

Australia	Pathway analysis of the flow account, which focuses on the sources of water as well as where water goes after use by economic activities and house holds, do not have stock account
Botswana, Namibia	Flow approach with partial information about stocks
Korea	Partial stock accounting, water quality degradation account and monetary emission account.

But mostly insufficient data i.e. inadequacy in the data structure for the stock account compels us to take up the flow accounting. Some countries as for example Botswana and Namibia have taken flow approach with partial information about stock or indicators of the state of the stock. Table below shows the status of literature.

Country Examples with respect to supply and use tables:

Countries	Important Points
Moldova	▪ Years considered 1994, 1998, 2000, 2002 ▪ SUT Matrix for 2002 ▪ Abstraction of surface water subdivided into abstraction from lakes, rivers, artificial reservoirs ▪ The returns into the environment are classified according to the types of water.
Sweden	▪ Year 2000 ▪ SUT tables was prepared at the river basin levels ▪ The following steps are performed: a) Municipalities located entirely within a river basin identified b) Municipalities intersecting at least two river basin- a more detailed analysis performed

	c) For municipalities which have all major urban areas located within a river basin, the entire municipality was allocated to that river basin where urban areas are located d) For the rest of the municipalities, data were allocated to the river basins according to the percentage of population in urban areas. ▪ The different components of supply and use tables at the river basin level concentrates on the abstraction and use of water by the manufacturing industries, for own use by households(estimated by applying water use connected to public water supply)
Netherland	▪ SUT tables prepared at the river basin levels ▪ Accounts compiled at the level of 40 COROP areas (official regional economic unit) ▪ Regional data on water abstraction and discharge are collected by Netherlands through National Water Survey prepared very four years. ▪ Data collected for four types of water use: ground water (fresh and brackish), surface water, sea water and water distributed by water supplying industries. Water use in agriculture is supplied by Agricultural- Economic Institute.
Australia	▪ Year 2002-03 ▪ River basins doesnot coincide with Australian Standard Geographical Classification (ASGC). The ASGC are defined by population and they are built in a hierarchical structure: statistical local areas are smallest units which can aggregated to form statistical sub-division which can be further aggregated to statistical division and finally to form a state.

	▪ River basins are not defined based on population criteria rather on hydrological characteristics of a region(they are defined as the area drained by stream and its tributaries where surface run off collects) ▪ Some steps that are followed to measure the agricultural water use are: a) Calculation of average application rate (water use per hectares) for the state and the crop. b) Calculation of Statistical local areas total agricultural water use c) Estimation of water use for river basins ▪ Tables and charts for abstraction of ground water and use of distributed water.
Botswana, Namibia and South Africa	▪ Per-capita water is taken as an indicator as it relates to the volume of water used to the population ▪ Comparison of water use among Botswana, Namibia and South Africa is taken

Source: United Nations Statistical Division (2006), Integrated Environmental and Economic Accounting for Water Resources

The Framework

We present water information to study the interaction between environment and the economy. In SNA framework we develop Supply and Use Tables. Physical Water Supply and Use Tables (SUT) describe water flows in physical units within the economy and between the environment and the economy.

The compilation of SUT allows for

- The assessment and the monitoring of the pressure on water quantities exerted by the economy
- The identification of the economic agents responsible for abstraction and discharge of water into the economy
- The evaluation of the alternative options for reducing water pressure

SUT can be presented at various levels of detail e.g by source of water, by supply institutions, By river basin etc. However, data availability is a major constraint for developing a consistent data base. There are data available from scattered sources. Collating that is a tremendous task. We tried to collate data from diverse sources to arrive at the SUT for West Bengal. Despite all the limitations we could come up with following sets of tables which can be taken as samples for future development of water account.

Table 1: Physical Water Supply and Use Table, West Bengal (million cum)

Use Table

	Agriculture	**Domestic**	**Manufacturing**	**Others**	**Total Use**
Ground water	20651.76	1434.15	5736.6	860.5	28683
Surface water	84412.8	5862	23448	3517	117240
Total use	105064.6	7296.15	29184.6	4378	145923

Supply Table

	Agriculture	**Domestic**	**Manufacturing**	**Others**	**Total Use**
Within economy		2918.46	8498.64	2000	13417.1
Reuse			291.84		291.84
Waste water to sewerage		2918.46	8206.8		11125.26
To the environment				2378	2378
irrigation	36772.6				36772.6
Lost in transport	10506.46	3648.08	1034.30		15188.84
Treated waste			10342.96		10342.96

Untreated waste water	42025.82	721.96	9308.68		52056.46
Total Supply	89304.88	7296.15	29184.6	4378	130163.6
Consumption	15759.68	0	0		15759.68

Case Study of Kolkata Municipal Corporation (KMC) delete

Physical SUT at River Basin level

River basin is a highly recommended spatial unit for integrated water management today especially in the wake of global warming. We could collect information from a variety of sources and have combined them in tables below.

Supply Table

	istricts	Municipalities/ Municipal Corporations	Utilisable ground water resource (mcm)	Net ground water draft (mcm)	Stage of ground water development(%)	total utilisable ground water of the river basin (mcm)	net total ground water draft (mcm)	stage of ground water development of rover basins	tc su w of ri ba
						21458	3882	82.46	6
	ankura		1180	171	0.15				
		Bakura, Bakura							
		Bishnupur, Bishnupur							
		Bishnupur, Sonamukhi							
	urdwan		2447	599	0.27				
		Sadar, Burdwan							
		Asansol, Jamuria							
		Kalna,Kalna							
		Burdwan,Memari							
		Katwa,Katwa							
		Katwa, Dainhat							
		Asansol,Raniganj							
		Burwan,Gushkara							
		Asansol,Asansol							
		Asansol,Kulti							
		Durgapur,Durgapur							
	akshin Dinajpur		496	63	0.13				
		Sadar, Balurghat							
		Gangarampur, Gangarampur							

	owrah		205	28	0.14				
		Sadar, Howrah							
		Sadar, Bally							
		Uluberia, Uluberia							
	ooghly		1289	402	0.31				
		Chinsurah, Chinsurah							
		Chinsurah, Bansberia							
		Serampore, Serampore							
		Serampore, Baidybati							
		Serampore, Rishra							
		Serampore, Konnagar							
		Serampore, Uttarpara-Kotrung							
		Serampore, Champadani							
		Serampore, Bhadreswar							
		Serampore, Chandannagar							
		Arambagh, Arambagh							
		Arambagh, Tarakeshwar							
	Ialda		818	243	0.3				
		Sadar, Englishbazar							
		Sadar, Old Malda							
	Iurshidabad		1657	816	49				
		Beharampur, Beharampur							
		Lalbagh, Murshidabad							
		Lalbagh, Jiaganj-Azimganj							
		Kandi, Kandi							
		Jangipur, Jangipur							
		Jangipur, Dhulian							
		Beharampore, Beldanga							
	adia		1322	739	0.56				
		Krishnagar, Krishnagar							
		Sadar, Nabadwip							
		Ranaghat, Santipur							
		Ranaghat, Ranaghat							
		Ranaghat, Birnagar							
		Ranaghat, Chakda							
		Ranaghat, Taherpur							
		Ranaghat, Cooper's Camp							
		Kalyani, Kalyani							
		Kalyani, Gayeshpur							
	orth 24 Parganas		10025	561	0.56				
		Barracpore, Kanchrapara							
		Barrackpore, Halisahar							
		Barrackpore,Nahai							
		Barrackpore, Bhatpara							
		Barrackpore, Garulia							

		Barrackpore, North Barrackpore							
		Barrackpore, Barrackpore							
		Barrackpore, Titagarh							
		Barrackpore, Khardha							
		Barrackpore, Panihati							
		Barrackpore, Kamarhati							
		Barrackpore, Baranagore							
		Barrackpore, North DumDum							
		Barrackpore, South DumDum							
		Barrackpore, DumDum							
		Barrackpore, New Barrackpore							
		Barasat, Barasat							
		Barasat, Gobardanga							
		Barasat, Ashokenagar-Kalyangarh							
		Basirhat, Baduria							
		Bidhannagar, Bidhannagar							
		Basirhat, Basirhat							
		Basirhat, Taki							
		Bongaon, Bongaon							
		Bongaon, Habra							
		Barasat, Madhyamgram							
		Barasat, Rajarhat-Gopalpur							
	outh 24 parganas								
		Alipore, Budge Budge							
		Alipore, Rajpur-Sonarpur							
		Alipore, Joynagar-Mazilpur							
		Alipore, Pujali							
		Daimond Harbour, Daimond Harbour							
		Alipore, Mahestola							
	ttar Dinajpur		651	199	31				
		Raiganj, Raiganj							
		Islampur, Islampur							
		Raiganj, Kaliaganj							
		Dal Khola							
	olkata								
						1368	61	0.04	5
	ooch Behar		1368	61	0.04				
		Coochbehar, CoochBehar							
		Dinhata, Dinhata							
		Tufanganj,Tufanganj							

		Mathabanga, Mathabhanga							
		Mekliganj, Haldibari							
		Mekhliganj, Mekhliganj							
						3119	34	0.02	?
	arjeeling		399	5	0.01				
		Sadar,Darjeeling							
		Kurseong, Kurseong							
		Kalimpong, Kalimpong							
		Siliguri, Siliguri							
		Kurseong, Mirik							
	lpaiguri		2720	29	0.01				
		Sadar, Jalpaiguri							
		Alipurduar, Alipurduar							
		Sadar, Mal							
		Sadar, Dhupguri							
	ekha					2738	644	0.36	?
	idnapore		2120	592	0.28				
	urba	Tamluk, Tamluk							
	urba	Contai, Contai							
	urba	Contai, Egra							
	urba	Tamluk, Haldia							
	urba	Tamluk, Paskura							
	aschim	Sadar, Midnapore							
	aschim	Sadar, Kharagpur							
	aschim	Ghatal, Ghatal							
	aschim	Ghatal, Chandrakona							
	aschim	Ghatal, Ramjibanpur							
	aschim	Ghatal, Ramjibanpur							
	aschim	Ghatal, Kripai							
	aschim	Ghatal, Kharar							
	aschim	Jhargram, Jharagram							
	urulia		618	52	0.08				
		Purulia, Purulia							
		Purulia, Jhalda							
		Purulia, Raghunathpur							

Data Source

1. administrative records of water supply and Sewerage departments
2. Surveys

3. Applications of coefficients e.g sectoral share in water use is guided by the coefficients that are available form various sources.

Emission Accounts

Emissions of water can constitute a major environmental problem and cause the quality of water bodies to deteriorate. Different types of pollutants generate d during production and consumption activities are discharged into water bodies either through the discharge of wastewater, with or without treatment, or directly. Some of the pollutants emitted into water resources are highly toxic and thus affect negatively the quality of the receiving water body and ultimately human health.

There is limited emissions data. Nevertheless, an attempt has been made.

Emissions to water are defined as direct release of a pollutant to water as well as the indirect release by transfer to an off-site wastewater treatment plant. Emissions to Water thereafter include the following:

- Discharge of pollutants contained in wastewater
- Discharge of substance to water resources such heavy metals and hazardous waste.

Ideally, emission accounts record the amount of a pollutant added to water by an economic activities during a reference period (generally the accounting year) and are expressed in terms of weight. They describe in terms of pollutants the part of water flows in the in the physical SUT that are destined to the environment either directly or through treatment plant. Emissions accounts cover:

1. pollutants added to wastewater and collected in sewage network;
2. pollutants added to wastewater discharged directly to water bodies
3. Selected non-point sources emissions i.e. emissions from urban ran-off and irrigation water.

The emissions accounts thus provide the description in terms of pollutants resulting from production and consumption, of the waste water flows.

Source of pollution are classified **in point source** and **non point source** emissions. Point source emissions include emissions from wastewater treatment plants, power plants, and other industrial establishments. Non point sources (or diffuse) of pollution are sources without a single point of origin or a specific outlet into a receiving water body. Pollutants are generally carried off the land by storm water run-off or may be the result of a collection of individual and small scale polluting activities which for practical reasons cannot be treated as point sources of pollution. The commonly used categories for non point sources include agriculture, forestry and urban areas.

Point source emissions are generally considered easier to measure since the point of emission to the water sources is clearly identified. This in turn allowed for the identification of the economic unit responsible for the emissions and for the measurement of the pollution content of the discharge at the precise location. Non point source of emission cannot be measured directly but need to be estimated through models which take into consideration several factors including the soil structure and the climatic conditions as well as the delay with which the pollutants reach the waste table. Further it is difficult to allocate non-point emission sources to the economic unit that generates them because of their nature.

Regarding industrial emissions the most water intensive industry in West Bengal is the pulp and paper industry which consists of around 12 plants. A special survey of these plants was conducted.

Table 2: Sources of Water and Discharge of Waste Water

	Nearby River	**Sources of water used by the mill**	**Place of discharge**
Mill 1		Deep tube well	Irrigation canal
Mill2		Deep tube well	
Mill3		Deep tube well	
Mill4	Ganges	Deep tube well	
Mill5		Deep tube well	

Mill6		Deep tube well	
Mill7	Darageswar	Deep tube well	Municipal drain
Mill8	Ganges	Deep tube well	Panchayat drain
Mill9	Bhagirathi	Deep tube well	Municipal drain
Mill10		Deep tube well	Canal
Mill 11		Deep tube well	Canal
Mill 12		Deep tube well	Canal
Mill13	Hoogly	Deep tube well	River and irrigation land

Source: Primary Survey

Table 3: Characteristics of Untreated Wastewater

	Volume (klit/d)	**BOD Mg/l**	**COD Mg/l**	**pH**	**SS Mg/l**
Mill 1	695	800	1936	5.01	842
Mill2	125	775	5900	4.13	1000
Mill3	250	350	1200	5	500
Mill4	12	150	500	6.5	250
Mill5	50	145	340	7.1	284
Mill6	14	140	1000	6.4	400
Mill7	254.3	164	1286.32	7.07	1092
Mill8	630	200	750	8.5	2000
Mill9	1230	750	680	6.5	1000
Mill10	140	205	500	6.5	800
Mill 11	100	270	562	5.5	68
Mill 12	11000	400	931	8.1	620
Mill13					

Table4: Characteristics of Treated Waste Water

Sl. No.	BOD (Mg/l)	COD (Mg/l)	pH	SS (Mg/l)
MINAS Standard	30	250	5.5 – 9	100
Mill 1	28.12	58.08	7.29	14
Mill 2	80	350	5.75	64
Mill 3	40	400	7.5	50
Mill 4	30	55	7.4	30
Mill 5	20	44	7.3	28
Mill 6	28	200	7	80
Mill 7	42.73	229	7.24	24
Mill 8	25	200	7.25	40
Mill 9	29	199.92	8.11	104
Mill 10	50	350	6.5	500
Mill 11	60	400	6.2	23
Mill 12	8.36	65.8	8.1	10.2

Source: Primary Survey

Table 5: Emission Details of the Plants

Sl. No.	Stack Height	SPM Mg/Nm^3	SO_2 Mg/Nm^3	NO_2 Mg/Nm^3	CO_2 V/V	CO V/V
Mill 1	33 (B) 9.14(DG)	416.43 76.94	48.08 33.05		6.4 6.4	0.2 0.2
Mill 2	33	276.67	12			
Mill 3	30.48					
Mill 4	30.5	46.7	21.7		9.4	0.3
Mill 5	30.48	639.07			4.8	0.2

Mill 6	21.4	39.6	29.7	11.8	39.6	0.2
Mill 7	36.5	2273			7.2	
Mill 8	38	312.86	78.76		5	<0.2
Mill 9	30	35.28			10%	
Mill 10	36.6					
Mill 11	6	130	280		9.2	<1%
Mill 12	50	109.52	275.1			<0.2

Source: Primary Survey

Table 6: **Permissible standard for parameters of paper mills**

Parameter	Permissible standard
BOD	30 mg/l
COD	250 mg/l
PH	5.5-9 mg/l
SS	100 mg/l

Source: Primary Survey

Evaluation of Water Quality Indices for Paper Mills

Abatement activity generally is for more than one pollutant. For example reduction of COD always entails some reduction in BOD. Often it is argued that the cost function needs to be specified in terms of multiple pollutants, so that marginal abatement cost can be computed for each pollutant separately. The policies as they exist today MINAS are set with respect to each pollutant separately. This gives rise to the added problem of inefficient use of water. As the MINAS are set in terms of concentration, there is option for the plants to meet the standards by using groundwater for dilution, though in two cases load is same. So the challenge is how to set a standard in terms of load and multiple pollutants. This necessitates development of quality index at the first step and then to think of appropriate standard. This itself is a very large research issue as limited literature is available in this field. In this chapter we attempt to estimate only the quality indices for the mills under consideration and try to compare the ranking of mills as per quality indices with the ranking based on one parameter only as has been shown in earlier chapter. Though pollution load would have been more useful but lack of information compels us to base our analysis on concentration data.

Water Quality Indices

The purpose of water quality indices is to give a single value to the water quality of a source on the basis of values of pollution parameters. Indices may be applied to specific locations or industries to determine the extent to which legislative standards and existing criteria are being met or exceeded. Effluents, containing organic and inorganic pollutants, generated from industrial activities are major cause of surface water quality degradation. Water quality and pollution level are generally measured in terms of concentration or load of pollutants. Different parameters like pH, BOD, COD etc., need to be monitored for proper assessment of water quality. Pollution abatement involves treatment of wastewater to bring the levels of BOD, COD, suspended solids and pH within specified tolerance limits. But in the previous chapter we have taken only BOD to calculate the marginal abatement cost of pollution. One reason for taking one parameter BOD is the possibility of existence of multicollinearity. But water quality depends not only BOD, but also depends on other parameters. Hence it will be more convenient to integrate the data pool in some way to produce a single number to reflect the water quality status. An attempt has been made in this chapter to construct a water quality based on four parameters namely BOD, COD, pH and SS.

The first modern WQI was formulated by Horton (1965), based on 10 most commonly measured water quality variables including DO, pH, coliform, alkalinity and chloride. Though the index is easy to calculate, it is highly subjective in nature. Water quality indices have not been used extensively in India. One of the first reported indices in India is Bhargava’s Index (1985). Bhargava identified 4 groups of parameters. The first group included the coliform, the second group included toxicants, the third group included odour and colour, the fourth group included nontoxic substances like chloride, sulfate etc. Ved Prakash developed the river Ganga index to evaluate the water quality profile of river Ganga and to identify the reaches where the gap between the desired and the existing water quality is significant enough to warrant urgent pollution control measures (Abbassi 1999b).

We have evaluated here the water quality index (WQI) of 12 paper mills taking into consideration the values of significance rating and weights for parameters of different mills as well as the quality rating for each parameter (Datta et al 2001).

Formulation of WQI involves series of judgments that will eventually determine the form and utility of the index. Some of the important requirements of water quality index (WQI) are:

i. The index should be sensitive to changes in the value of water quality parameter relevant for a particular beneficial use.
ii. The index should significantly decrease when some critical parameter exceeds the permissible quality level for a given use.
iii. The index should remain unchanged when the value of a parameter changes within the permissible level.
iv. The change in the index should be more in respect of a parameter which has greater significance.
v. The variation in the index should reflect the different levels of significance of a single parameter for the different uses.

There are four stages in the development of (WQI).

(a) Parameter selection

(b) Transformation of parameter estimates to a common scale

(c) Assignment of weightage to all the parameters

(d) Aggregation of individual parameter

Methodology for Calculation of WQI

There are two kinds of methods to calculate WQI – aggregative method and multiplicative method.

Method 1: Aggregative method

The WQI considered in the aggregative form is of the form

$WQI_a = \sum q_i w_i$ ……………………………….(1)

Where,

WQI_a =the aggregative water quality index, a number between 0 and 100

q_i = the quality rating of the i-th parameter, a number between 0 and 100

w_i = the unit weight of the i-th parameter a number between 0 and 1;

$\sum w_i = 1$

n = number of parameters

In this type of index, the weighted mean indices do not permit sufficient lowering of the index if any one significantly relevant parameter exceeds the permissible limit.

Method 2: Multiplicative index

In the case of industrial waste multiplicative form of index may be considered, which is given by

$$WQI_m = \Pi(q_i)^{w_i} \quad \text{..} \quad (2)$$

Where,

WQI_m = the multiplicative water quality index, a number between 0 and 100

q_i = the quality rating of the ith parameter, a number between 0 and 100

w_i = the unit weight of the ith parameter a number between o and 1

$\sum w_i = 1$

n= number of parameters

In the multiplicative index, weights to individual parameters are assigned based on a subjective opinion. The weight reflects a parameter's significance for use and has considerable impact on the index.

While calculating the value of quality rating (q) and weightage (w), the DELPHI method, developed by Rand Corporation has been utilized. This is an opinion-based technique which can be utilized to extract information from a group of respondents. The procedure used in formulating this Water Quality Index (WQI) attempted to incorporate many aspects of DELPHI process. A panel of persons with expertise in water resource management has been considered. In the initial stage anonymity of the individual responses of the panelists has been ensured. The panel was exposed afterwards to view the total judgement of all respondents to obtain the final values as the positive outcome of group interaction. The latter has been achieved through controlled feed back of group response.

Calculation of Water Quality Index:

Step 1: Significance Rating of Water Quality Parameters

A panel of 15 persons with expertise (the list of experts has been given in the Appendix 5.1) in water quality management has been selected for the study. They have been asked to rank the water quality parameters for industrial wastewater according to their contribution to overall quality of surface water. Based on the polluting effect of the parameter in consideration relative to other parameters. The rating has been done on a scale of 1 (highest polluting effect) to 5 (lowest polluting effect), each of the parameter represents only a part of the overall quality, thus parameters of lower importance even cannot be discarded, since they are still part of the overall quality.

Step 2: Determination of Weightage of Parameters

In the next step, arithmetic mean has been evaluated on the rating series of the experts, to arrive at the "mean of all significance rating" for each individual parameter. Then to convert the rating into weights, a temporary weight of 1.0 has been assigned to the parameter, which received the highest significance rating. All other temporary weights have been obtained by dividing the highest rating by the corresponding individual mean rating of the parameters. Each temporary weight has then been divided by the sum of all temporary weights to deduce the final weights (w_i), which must sum up to one. A total weight of 1 has thus been distributed among the parameter to reflect the selective importance of the parameter in question. The weightage level assigned to a parameter is an indicative of the degree to which water quality may be affected by the particular parameter.

Table 7: Significance and weights for parameters of the paper mills

Parameter	Mean of all significance ratings	Temporary weights	Final weights (w_i)

	returned by respondents		
BOD	1.3	1	0.365
COD	1.8	0.72	0.263
PH	2.3	0.56	0.204
SS	2.8	0.46	0.168

Source: Estimates based on primary survey

In the above table we see that BOD has got the highest significance rating with final weights being 0.365. So, the worst parameter is BOD. Then comes COD, pH and SS.

Step 3: Quality Rating for Different Parameters

After significance rating, the respondents (experts) have been asked to assign values for the variation in level of water quality produced at different concentration for 4 important parameters. This has been accomplished by utilizing a series of graphs. On the vertical axis, levels of "Water Quality rating from 0 to 100 have been indicated, while various levels (or concentration) of the particular parameter have been arranged along the horizontal axis. Graphs developed for different parameter have been shown in the appendix. The respondents have been asked to draw in a curve, which in their judgement, represented the variation in level of water quality produced by the various possible measurement of each respective parameter (The questionnaire for quality rating is given in the Appendix 5.2). This information has been later used by combining the "judgement" of all respondents to produce a set of" average curve" one for each parameter (Shown in Appendix 5.3-5.5). In this way we can calculate the quality rating (q_i) for different parameters. It should be pointed out that the experts do quality ratings keeping in mind the permissible standard for the parameters. Permissible standard for different parameters for paper mills is given in the table 5.2.

Step 4: Quality Rating for Different Parameters before Treatment for the Mills under Consideration

Water quality ratings for different parameters for the paper mills have been presented in the table 5.3. The quality of wastewater of the paper mills under consideration is given by the levels of BOD, COD, pH and SS. We have got the parameter data from the field survey. In the table 8 we have calculated the quality rating of the parameters of wastewater before treatment. The rating of the parameter indicates the quality of the effluent as judged by the panel of experts. As the pre-treatment parameter values are high, the rating of the parameters of all the mills turns out to be poor.

Table 8: Effluent Quality and Quality Rating for Different Parameters before Treatment

	BOD		**COD**		**PH**		**SS**	
	Quality Mg/l	**Rating (q_i)**	**Quality Mg/l**	**Rating (q_i)**	**Quality Mg/l**	**Rating (q_i)**	**Quality Mg/l**	**Rating (q_I)**
Mill 1	800	6	1936	1	5.01	30	842	5
Mill 2	775	6	5900	1	4.13	30	1000	2
Mill3	350	15	1200	2	5	30	500	8
Mill4	150	23	500	12	6.5	50	250	18
Mill 5	300	17	340	20	7.1	54	284	15
Mill 6	140	24	1000	2	6.4	65	400	7
Mill 7	164	22	1286	2	7.01	70	1092	2
Mill 8	200	20	750	8	8.5	60	2000	2
Mill 9	750	6	680	10	6.5	62	1000	2
Mill 10	200	20	500	12	6.5	63	800	5
Mill 11	270	18	562	12	5.5	50	68	50
Mill 12	400	12	931	2	8.1	64	620	6.5

Source: Estimation based on Primary Survey

Step 4: Quality Rating for Different Parameters for the Mills under Consideration after Treatment

Following the same procedure as discussed above we can calculate the quality ratings of different parameters after treatment of wastewater. In the table 9 we have given the evaluated quality rating of the parameters after treatment of wastewater in the ETP. The water quality certainly improves after treatment.

Table9: Effluent Quality and Quality rating for Different Parameters after Treatment

	BOD		COD		PH		SS	
	Quality Mg/l	Rating (q_i)	Quality Mg/l	Rating (q_i)	Quality Mg/l	Rating (q_i)	Quality Mg/l	Rating (q_i)
Mill 1	28.12	82	58.08	98	7.29	83	14	99
Mill 2	80	32	350	20	5.75	65	64	95
Mill3	40	45	400	25	7.5	80	50	96
Mill4	30	70	55	98	7.4	81	30	98
Mill 5	70	30	44	98	7.3	82	28	98
Mill 6	28	82	200	80	7	98	80	94
Mill 7	42.73	40	229	80	7.24	84	24	98
Mill 8	30	80	200	80	7.25	84	40	97
Mill 9	28	82	200	80	8.11	64	104	90
Mill 10	50	35	350	40	6.5	80	500	50
Mill 11	60	32	400	45	6.2	78	23	98
Mill 12	8.36	95	66	95	8.1	64	10.2	99

Source: Estimation based on primary survey

Step 5: Classification of Wastewater on the Basis of Water Quality Index (WQI)

We can see from table 5.3 and table 5.4 that quality ratings are not uniform for each parameter for the mills. So we need to construct a water quality index depending upon the rating values for each parameter. Now, with the help of the formula in equation (1) for aggregative method, we can calculate the water quality index of wastewater for the paper mills. The values of the parameter may lie between 0 and 100. The classification of wastewater based on the value of WQI has been constituted in the table 5.5.

Table 10: WQI for Effluent Quality

Sl. No	**WQI**	**Description**

1	81-100	Excellent
2	61-80	Good
3	51-60	Moderate
4	41-50	Poor
5	Upto 40	Very poor

Source: Datta et al (2001)

Step 6: Water Quality Index for Wastewater from Mills before Treatment

Based on the above classification we have evaluated the performance of the paper mills by judging their WQIs. This has been presented in the tables 5.6. The WQI of the 12 paper mills has been evaluated taking into account the values of weights as given in table 5.1 as well as the quality rating for each parameter as given in the table 5.3.

Table 11: Water Quality Index of the Paper Mills before Treatment

Mill	**Water Quality before treatment**	
	WQI	**Description**
Mill 1	8.54	Very poor
Mill 2	4.54	Very poor
Mill3	12.68	Very poor
Mill4	28.70	Very poor
Mill 5	30.37	Very poor
Mill 6	24.02	Very poor
Mill 7	24.81	Very poor
Mill 8	21.60	Very poor
Mill 9	18.73	Very poor
Mill 10	24.95	Very poor
Mill 11	32.60	Very poor
Mill 12	18.89	Very poor

Source: Estimates based on primary survey

In the above table the values of WQI for the 12 paper mills before treatment of wastewater is presented. As expected, the water quality is very poor for all the mills. The values lie between 7.92 to 28.32 and so below 40, indicating very poor quality of wastewater. This conclusion is in line with our presentation in chapter II.

Step 7: Water Quality Index for Wastewater after Treatment

For assessing water quality improvement after treatment of wastewater we have evaluated WQI after treatment for all the paper mills following the same methodology as mentioned before.

Table 12: Water Quality Index of Paper Mills after Treatment

Mill	Water Quality after treatment	
	WQI	**Description**
Mill 1	89.76	Excellent
Mill 2	49.01	Poor
Mill3	56.09	Moderate
Mill4	84.87	Excellent
Mill 5	70.51	Good
Mill 6	86.56	Excellent
Mill 7	69.77	Good
Mill 8	84.08	Excellent
Mill 9	81.85	Excellent
Mill 10	46.96	Poor
Mill 11	56.68	Moderate
Mill 12	92.35	Excellent

Source: Estimates based on primary survey

The results thus obtained for the above paper mills before and after treatment give an indication of the degree of treatment to be adopted by the units for satisfying the statutory compliance regarding the quality of wastewater. The results in the above table also indicate that performances of all the mills are not the same. Out of the 12 mills 7 mills have performed excellent, 1 mills are good, 2 mills are moderate and 2 mills are poor. It is expected that plants with better quality of water should have done more abatement efforts. WQI is a composite quality index representing all the major pollution parameters. In earlier chapter we have used BOD as single parameter to assess abatement performance of the mills. Though a single parameter index like BOD does not represent the total water quality as shown by WQI but former being a major component we expect a high correlation between after treatment WQI index and after treatment BOD measurements. In the 5.8 table we give the value of BOD after treatment (as referred in table 2.22) and WQI after treatment.

Table 13: Levels of BOD and WQI after treatment

Mill	**BOD after treatment**	**WQI after treatment**
Mill 1	28.12	89.764
Mill 2	80	47.316
Mill3	40	56.085
Mill4	30	84.865
Mill 5	70	70.514
Mill 6	28	86.558
Mill 7	42.73	69.766
Mill 8	30	84.081
Mill 9	28	79.992
Mill 10	50	46.955
Mill 11	60	56.678
Mill 12	8.36	90.486

Source: Primary Survey

Table 14: Water Consumption by the Paper Mills and Water Cess Paid

	Production Tpd	Industrial Cooling/ Boiler Kld	Domestic Purpose Kld	Processing Kld	Total Water Consumption Kld	Water Intensity	Waster cess Paid to the government (Rs.)
Mill 1	23	29	11	798	838	36.43	40000

Mill2	10	49	3	158	210	21.00	5400
Mill3	20	50	30	300	380	19.00	20000
Mill4	6	4.5	3.5	15.5	23.5	3.92	324
Mill5	8	6	4	65	75	9.38	10000
Mill6	10	6	5	15	26	2.60	1264
Mill7	10	15	6	254.3	275.3	27.53	10500
Mill8	40	22.5	160	800	982.5	24.56	28920
Mill9	25	150	14	1610	1774	70.96	43590
Mill10	15	30	15	180	225	15.00	5118
Mill 11	18	25	20	220	265	14.72	2625
Mill 12	70	320	1194	11950	13464	192.34	328744
Mill13							

Source: Primary Survey

Monetary valuation: Abatement Cost Approach

Estimation Procedure Adopted in the Study

We have used two methodologies for our purpose to estimate marginal abatement costs. We assume here that prices of the variable inputs are constant and there is only one pollutant in the influent. Our cost function then involves three variables i.e. the volume of the wastewater stream or flow size (F), BOD in the influent or BOD before treatment (BODB) and BOD in the effluent or BOD after treatment (BOD). We can think of the resulting cost function as a short run operating cost function (Mehta et al 1997). Generally short run cost function of a neoclassical firm depends on capital cost. Capital consists of land, structures and equipments for ETP. As the valuation of some of these items, particularly land are difficult, we take flow size (F) as a proxy for capital equipment.

Methodology I

Following existing literature we use equations 4.1 and 4.2. Equation (4.1) has been used by James and Murthy (1996) and equation (4.2) which is less restrictive than equation (4.1) has been used by Ganguly and Roy (1997), Goldar and Pandey (1997). The advantage of these equations are that we may be able to compare results through these equations and they are reasonably good specifications barring one or two problems. These equations use Cobb-Douglas production functions to derive the cost function.

$C = BF^{\eta} (BODB / BOD)^{\alpha}$ ---------- (4.1)

$C = BF^{\eta} (BODB)^{\alpha} (BOD)^{\beta}$ ----------(4.2)

Given the form of cost function we can derive the marginal abatement cost (MAC) function. The marginal abatement cost of pollution is the cost of removing one unit of pollutant namely BOD from the waste stream. Marginal cost of removing 100 grams of pollutant removed (R) at different levels of effluent quality is obtained in the following way.

$\delta C/\delta BOD = A\, \beta\, F^{\eta} (BODB)^{\alpha} (BOD)^{\beta-1}$

R = F (BODB - BOD) Where R is expressed in 100 grams per year, F in kilo liter per day, C in Rs. lakhs and BOD in mg/l. Differentiating the above equation taking into account their units (Mehta et al 1997) we get

$\delta BOD / \delta R = 10^7/355\ F = 28169\ F$

$MAC = \partial C / \partial R = \delta C/\delta BOD \times \delta BOD / \delta R = -28169\ B\ F^{\eta-1}\ (BODB)^{\alpha}\ (BOD)^{\beta}$

But the obvious problem with these forms is that even if BOD level before treatment is same as BOD level after treatment i.e. there is no abatement, there does appear positive abatement cost indicating the possibility of overestimation of abatement cost. Again on theoretical grounds it is required that the abatement cost curve should be a downward sloping convex curve with respect to post treatment BOD. Thus abatement cost function should satisfy the following restrictions.

$\partial C / \partial BOD < 0$ and $\partial^2 C / \partial^2 BOD > 0$

Methodology II

The lacunae in using equations (4.1) & (4.2) may be partially addressed if it is given by the following equation i.e.

$C = B\ F^{\eta}\ (BODB - BOD)^{\gamma}$ ………………(4.3)

Here only the flow size and difference in pollution concentration is considered. But if there is significant variation among firms in regard to BODB and BOD, then one of these two should be introduced as an additional variable. It is better to introduce BOD as an additional variable in the cost function rather than BODB because the convexity condition will be preserved even if $\gamma < 1$. So, the equation is given by

$C = B\ F^{\eta}\ (BODB - BOD)^{\gamma}\ (BOD)^{-\theta}$ ………………..(4.4)

Given the form of cost function of equation (4) we can derive the marginal abatement cost (MAC) function.

$\delta C/\delta BOD = -B\ \gamma\ F^{\eta}\ (BODB - BOD)^{\gamma-1}(BOD)^{-\theta} - B\ \theta\ F^{\eta}\ (BODB - BOD)^{\gamma}\ (BOD)^{-\theta-1}$

$\delta BOD / \delta R = -28169\ F$

$MAC = 28169\{B\gamma\ F^{\eta-1}(BODB - BOD)^{\gamma-1}(BOD)^{-\theta} - B\ \theta\ F^{\eta-1}(BODB - BOD)^{\gamma}\ (BOD)^{-\theta-1}\}$

We have estimated MAC using both the above two methodologies to see whether there is any substantial difference in estimated values for differences in methodologies.

IV.2.3 Data Source

Coverage of the study has been restricted by the availability of the data. The results of the present study are based on the primary data collected from the field survey of 12 Pulp and Paper mills in West Bengal. The data used for estimating Marginal cost of BOD-5 removal cover 12 small pulp and paper mills producing a variety of paper and paper products with capacity varying from 7 MT (metric tonnes) / day to 94 MT/day. The sample flow size varies directly with the size of the mill.

IV.2.4 Estimation of Total Costs of Abatement

For estimation of total costs of BOD removal we have followed two specifications given by two equations (2) and equation (4). All these equations are in nonlinear form. The log-linear forms of equation (2) and equation (4) are respectively given by

$$\ln C = \ln B + \eta \ln F + \alpha(BODB) + \beta(BOD) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (4.5)$$

$$\ln C = \ln B + \eta \ln F + \gamma \ln(BODB - BOD) - \theta \ln(BOD) \quad \ldots\ldots\ldots\ldots\ldots..(4.6)$$

The stochastic log-linear forms of these equations have been finally estimated with Ordinary Least Square (OLS) method and the estimated equation describe the annual cost of BOD removal. The table 4.1 presents the final regression results for equation (4.5).

Table 15: Estimation Results of Equation (4.5)

Explanatory Variables	Parameter values	t	Significance at 5% level of significance
Constant	0.252	0.193	Insignificant
LnF	0.260	2.313	Significant

LnBODB	0.510	1.815	Insignificant
LnBOD	-0.586	-1.225	Insignificant
R^2	0.853		
Adjusted R^2	0.798		

Source: Estimates based on primary data

The estimated equation shows that all the coefficients except one are significant at 5% level and all the coefficients have expected signs. The signs indicate that total abatement cost increases as the flow size increases, pre treatment BOD i.e. BODB increases and the post treatment BOD i.e. BOD decreases. The elasticity of cost with respect to flow size is found to be less than one, showing economies of scale in water pollution abatement. High R^2 justifies high explanatory power of the specification.
The estimation results of equation (4.6) is presented in the table 4.2

Table 16: Estimation Results of Equation (4.6)

Explanatory Variables	Parameter values	t	Significance at 5% level
Constant	0.426	0.343	Insignificant
LnF	0.261	2.396	Significant
Ln(BODB – BOD)	0.464	1.911	Insignificant
LnBOD	-0.541	-1.895	Insignificant
R^2	0.858		
Adjusted R^2	0.804		

Source: Estimates based on Primary Data

Here all the coefficients have expected signs and all but one are significant at 5% level of significance. The signs indicate that abatement cost increases as the flow size increases, BOD difference increases, and the post treatment BOD decreases. The partial derivative of cost with respect to difference in BOD is positive, implying that higher the amount of pollution reduction, the greater is the cost of abatement. High R^2 justifies high explanatory power of the specification.

IV.2.5 Estimation of Marginal Abatement Costs and Tax Rates

Now we turn to the calculation of marginal abatement cost (MAC), which can be used as tax rate under polluter pay principle to be imposed on each firm. MAC here represents the costs of reducing 100 grams of BOD per annum.

Table 17: Calculated Marginal Costs in Rupees for Reduction in 100 grams of BOD for Maintaining Standard at 30 mg/l.

	Flow Size (Kld)	MAC –1 (Methodology1) Rs.	MAC-2 (Methodology2) Rs.
Mill 1	695	23.01	20.73
Mill 2	125	80.58	73.89
Mill 3	250	32.17	31.02
Mill 4	12	197.52	215.05
Mill 5	50	67.52	72.96
Mill 6	14	170.13	186.97
Mill 7	254.3	21.58	22.56
Mill 8	630	12.20	12.34
Mill 9	1230	14.59	13.1
Mill 10	140	37.14	38.06
Mill 11	100	55.51	55.26
Mill 12	11000	2.09	1.93

Source: Estimates based on primary data

Marginal costs of 100 grams of BOD removal at MINAS point (30 mg/l) for all the twelve firms with varying flow sizes from a maximum of 11000 kld and a minimum of 12 kld are reported in Table 4.3 for varying BODB concentrations. As have been mentioned in Chapter II, out of these 12 mills, only Mill 12 is large, Mill1, Mill 8 and Mill9 are medium and all other mills are small in size. MAC-1 and MAC-2 represent respectively marginal abatement costs following methodology 1, 2 respectively. For example MAC to achieve state standard for firm1 is Rs. 23.01 following methodology 1, implying that for 100 grams of BOD reduction at MINAS point, plant 1 has to incur Rs. 23.01. Similarly we can say that for 100 grams of BOD reduction to maintain the MINAS point, the firm I has to incur Rs. 20.73 by methodology II. The results clearly indicate that MACs are not highly diverging and depend not so much upon the methodologies adopted to estimate the abatement cost function.

We can calculate average abatement cost and make a comparison with marginal abatement cost. Average abatement cost is defined as the average cost for reduction of 100 grams of BOD. It is defined as:C/[(BODB-BOD)*F] where C is water pollution abatement cost, BODB is BOD level before treatment, BOD is after treatment and F is flow size. We see that average abatement cost differs among the plants with the minimum being Rs. 0.60 and maximum being Rs. 112.27. We see that there are economies of scale in pollution reduction as the flow size increases the average abatement cost tends to decline. We see that marginal abatement cost is much higher than average abatement cost for each plant also the average abatement cost is falling. So there exists scale economies.

Table 18: Average Abatement Cost of 100 grams of BOD Reduction

	Water pollution Abatement cost (Rs. Lakhs)	Flow Size (Kld)	BODB mg/l	BOD mg/l	Average Abatement cost for 100 gms reduction in BOD (Rs.)
Mill 1	25.9819	695	800	28.12	1.38
Mill 2	12.6994	125	775	80	4.18
Mill 3	11.3365	250	350	40	4.18
Mill 4	4.2311	12	150	30	83.95
Mill 5	5.2619	50	145	20	24.05

Mill 6	6.1616	14	140	28	112.27
Mill 7	5.1444	254.3	164	42.73	4.77
Mill 8	35.6900	630	200	25	9.25
Mill 9	27.7777	1230	750	29	0.89
Mill 10	4.6746	140	205	50	6.15
Mill 11	9.3492	100	270	60	12.72
Mill 12	91.0977	11000	400	8.36	0.60

Source: Estimates Based on Primary Survey Data

We have earlier discussed that the tax rate should be equated with marginal abatement cost to get the optimum tax rates for different mills. Given the flow size and post treatment BOD level of different plants, we can calculate the tax bill of the plants. We have also calculated tax bill as a percentage of turnover for different mills. These are presented in the table 4.5.

Table 19: Tax Bill as a Percentage of Turnover

Mill	Tax bill (Rs.)	Turnover (Rs.)	Tax bill as a percentage of turnover
Mill 1	1573928	120750000	1.303
Mill 2	2820300	47250000	5.969
Mill 3	1125950	84000000	1.340
Mill 4	248875.2	29400000	0.847
Mill 5	827120	33600000	2.462
Mill 6	233418.4	56700000	0.412
Mill 7	820150.8	56000000	1.465
Mill 8	807030	322000000	0.251
Mill 9	1758679	262500000	0.670
Mill 10	909930	57750000	1.576
Mill 11	1165710	69300000	1.682
Mill 12	672687.4	17469431000	0.004

Source: Estimated from the primary data

We see tax bill as a percenatge of turnover varies from a minimum of 0.004% to maximum of 5.96%. The larger firms have to spend a smaller share of their turnover towards payment of pollution taxes.

IV.2.6 Marginal Abatement Cost Curves

The estimates we have done if extended for varying (in addition to MINAS: 30 mg/l) BOD concentration after treatment can be used to get marginal abatement cost (MAC) curves. Calculations for all the 12 firms of marginal cost of removing 100 grams of BOD in the flow after treatment for a specified level of initial BOD concentration (maximum = 800mg/l, mean=237.5 mg/l, median=362.4 mg/l) are shown in the tables in the appendix 4.1, 4.2 respectively. We have shown marginal abatement cost curves for two plants in the Appendix 4.4 (when BODB =800 mg/l), Appendix 4.5 (BODB =237.5) and Appendix 4.6 (BODB = 362.4). The maximum, median and mean values of BODB are obtained on the basis of the reported data. From the figures we observe the following things.

(1) It is expected that marginal abatement cost rises with fall in concentration of BOD in treated water i.e. initial reductions in BOD levels should be achieved with relatively lower cost than at a later stage.

(2) Firms with varying sizes of flow (reflecting the scale of production) face different marginal abatement cost curves for BOD with varying slopes. The decline in estimated marginal cost of BOD removal for large - size firms (with larger flow sizes) shows the importance of scale economies in wastewater treatment. Other things remaining constant, the same level of BOD removal would cost less with a rise in the volume of water entering the treatment plant.

IV.2.7 Policy Implications:

MAC estimates show that abatement cost increases as more and more of the pollutants are removed. Findings justify the theoretical contention in favour of a mixed instrument. We have derived the tax rates for the paper industry, which may provide incentive towards pollution abatement through market-based instrument. If the tax rate is imposed on all the firms then this will induce firms to take low waste technology in the production process. As suggested in the literature tax rate should represent MAC at MINAS point. (i.e. MAC at 30 mg/l in the case under study). This notion would lead us to suggest a separate tax for each of the firm in the industry. The tax rates for each of the firm have been presented in the table 4.3. The rate of tax varies across firms and the range of variation is between (Rs.2.09 to Rs.197.52) under methodology I, between (Rs. 1.93 to 215.05) under methodology II per 100 gm. of BOD of maintaining the MINAS standard. It should be mentioned that there are large variations in MAC across firms. The ratio between the highest and the lowest MAC are about 100:1. This happens because flow sizes of the firms are largely different because of the size of the mills. In fact the ratio between the highest and the lowest flow size are about 900:1. As in other studies, the variations in flow sizes are not so high, the variations in MACs are also not so high. For Mill 12, Marginal abatement cost stands out to be Rs.2.09 which is comparable to other results. If two outliers (Mill 4 and Mill 6 for which the flow size is very low) are excluded the range of variation lies between Rs.2.09 to 80.58 under methodology I, between Rs. 1.93 to 73.89 under methodology II.

Ganguli and Roy (1997) have done the marginal abatement cost calculation based on the secondary data compiled from the Bureau of Industrial costs and Prices (BICP, 1990) Report on Water Audit of Pulp and Paper Industry. BICP was set up in January 1970 as an expert body to tender advice to the Government on various issues like cost reduction, improvement of Industrial efficiency and pricing relating to industrial products. The data used for estimating MAC of BOD-5 removal cover 11 large paper mills producing a variety of paper and paper products with capacity varying from 40 MT/day to 300 MT/day. Marginal cost of abatement for the firms of highest flow size and lowest flow for maintaining MINAS are respectively Rs. 1.54 and Rs. 6.88. The study of Meheta et al (1997) suggests that the pollution control authority could set its charges between Rs. 1.35 to Rs. 1.45 per 100 grams of BOD reduction. Calculations of Goldar and Pandey show that a tax rate of Rs. 3.5 per 100 grams of BOD, the distillary will bring down BOD concentration level to MINAS. The study of

Dasgupta et al (1996) shows that MAC ratio between small and large facilities can be as high as 30:1. All these studies show that there are large variations in the MAC. So large savings could be realized in an emission charge regime which equalized the marginal price of pollution across platns. The presence of scale economy indicates the economic viability of large-scale treatment plants like Common Effluent Treatment Plants (CETP). In this chapter we have discussed the marginal abatement cost calculation, as it is important for tax rate calculation. But the problem with this analysis is that in calculating marginal abatement cost we have considered only one parameter namely BOD. But the overall quality of water depends also on other parameters like COD, pH and SS and firms adopt measures to control all the parameters in varying degrees. In the next chapter we have considered how firms perform in terms of overall water quality. So we have calculated water quality index to show how the overall water quality has changed because of the regulation across firms.

Monetary Valuation: Damage cost approach

Fifty percent of the districts in the state of West Bengal in India are exposed to arsenic-contaminated water (Guha Majumdar, *et. al.*, 1998). A large number of people have been diagnosed with symptoms of arsenic poisoning even though much of the at-risk population has yet to be assessed for arsenic-related health problems (Guha Majumdar, *et al.*, 2000). Evidence of arsenic contamination was first identified in the 1980s, but by the mid-1990s it was clear that this constituted a public health crisis.

Arsenic is a shiny metalloid that dissolves in water. Humans ordinarily cannot detect, i.e., without water testing through appropriate technologies, its presence before it is too late. We can neither see, nor taste, nor smell whether the water we drink is contaminated with arsenic compounds. A large number of studies have shown that arsenic in drinking water can cause bladder, lung, kidney, liver and skin cancer. Arsenic can harm the central and peripheral nervous systems as well as heart and blood vessels, and can cause serious skin problems. It may also cause birth defects and problems in the reproductive system. In a developing country, attribution of medical expenditure to arsenic-related diseases imposes an extra burden on the already overburdened public provision of medical care. While other parts of India also have arsenic contamination, such contamination is quite acute in West Bengal.

The basic source of arsenic in West Bengal is geological--the arsenic is released to groundwater under naturally occurring aquifer conditions. Arsenic is generally detected in very shallow aquifers--between 30-70 meters--while deeper aquifers tend to be arsenic free. Over the last two decades in West Bengal, untreated tube-well water was heavily promoted as a safe alternative to microbiologically unsafe untreated surface water. Further, almost no restriction was imposed on withdrawal of underground water for irrigation. Massive and extended use of groundwater (Central Ground Water Board, 1999) for agriculture resulted in the lowering of the water table, leading to the mixing of arsenic in the sulphide rock with intruding oxygen, which subsequently dissolved in water that was used for drinking purposes.[1]

While several studies have looked into the issue of arsenic contamination, most existing studies (Chakraborty, *et al.,* 1987,1994, 1996; Dang, *et al.,* 1983; Gorai, *et al.,* 1984; Guha Majumadar, *et al.,* 1984, 1989, 1999, 2000, 2001) explore geological and climatalogical features, scale of the problem in terms of population coverage , the intensity and variety of health problems, and the technologies for arsenic removal. None of the studies cited above addresses the economic dimension to welfare loss and hence the associated costs and benefits of arsenic contamination and removal. A recent study by Ahmed, *et al.,* (2002) attempts to assess the WTP for piped water in arsenic-affected areas of Bangladesh.

The main objective of this paper is to assess the costs of arsenic contamination to households. In other words, this paper seeks to quantify the benefits to households in West Bengal of using arsenic-free water. Currently various plans are in place to solve the problem of arsenic contamination. However, while the costs associated with such

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[1] Appendices 1 and 2 show the deltaic plain starting from the west at Bhagirathi river to the east at Chittagong hills in Bangladesh, which has the highest incidence of arsenic.

plans are known, little is known about the value of benefits. This paper addresses the basic issue of good quality (that is, arsenic-safe) water as a scarce resource. Within such a context, we analyze the household demand for arsenic-safe drinking water.

II. Theoretical Framework

There is a vast literature (Grossman, 1972; Freeman, 1993; Courant and Porter, 1981; Cropper, 1981; Gerkin and Stanley, 1986; Harrington and Portney, 1987; Murty, *et al.*, 2003; Roy, *et al.*, 2003) that exploits an understanding of the behavioural responses of households to poor environmental quality in order to value the benefits of improvement in quality. This study similarly uses the household health production function model consisting of a household health production function and household demand function for mitigating and averting activities to estimate the benefits from a decline in arsenic concentration in ground water.

Households purchase market goods and/or allocate leisure time to produce consumable goods which give them utility. Since poor water quality can have a profound effect on human health, rural households often undertake various averting and adaptive actions to either decrease the exposure level of their family members to unsafe water or to alleviate the health effects of consuming arsenic-contaminated water. In West Bengal, households spend time or money to access arsenic-free water and medical treatment. Household actions to avert, mitigate and adapt to arsenic-contaminated ground water enter the utility function along with market goods.

Following existing literature, particularly Freeman (1993), we consider an individual utility function of the form

(1) $U = U(X, L, S)$

where X represents expenditures on all non-health related goods, L represents consumption of leisure and S the time spent sick.

$U_X > 0, U_L > 0, U_S < 0$

We assume that the sickness of an individual depends on exposure to pollution due to arsenic contamination, **p**, the adaptive or mitigating activities such as medical treatment **b**, stock of health capital, **h,** and stock of human capital, i.e., education, **e**. The health production function can be written as:

(2) $S = s(p, b, h, e)$

where $S_b < 0$, $S_p > 0$ and S_{bb}, $S_{pp} \neq 0$.[1]

One of the determinants of health status from arsenic contamination is the exposure or dose (cumulative or one time) of arsenic. So the variable, **p,** mentioned in (2) represents the exogenous environmental condition that depends on the concentration of arsenic in water, **c**, and the extent of averting[3] activity **a**, undertaken by the household to avoid or reduce exposure to pollution.

(3) $p = p(c, a)$

$p_c > 0$, $p_a < 0$

and by substitution

(4) $S = s(c, a, b, h, e)$

$S_c > 0$, $S_a < 0$, $S_b < 0$, $S_h < 0$, $S_e < 0$

[1] Assumption of non- zero second order derivative implies non-linearity in effect of medical expenditure and arsenic concentration on sickness. There is no unanimity about the direction of these effects that can be gleaned from dose response studies in arsenic literature (Adair et al, Chaudhuri et al.(2000), Rahman et al. (2003), Chakraborty et. al(2001), Sengupta et. al (2004). However, there are studies which do not rule out possibility of threshold and non linearity and possibility of U-shaped relation (Commission on Life Sciences 1999). Though USEPA accept (London Group, http://www.es.ucl.ac.uk/research/lag/as/) linearity, our assumption of non linearity is more in line with other studies on impact of pollution on health and is grounded in curvature property of the production function, shapes of pollution abatement cost and damage cost curves and some field observations.

[3] Averting costs are incurred to avoid the health impact. They reflect the cost of alternative action to achieve the same utility from the same end use activity, that is, drinking water. Mitigation costs are incurred to reduce damage after the exposure has occurred. We also refer to mitigating costs as adaptive costs.

Given the utility function in equation (1) the individual chooses X, L, a and b in such a way so as to maximize utility subject to the full-income budget constraint (Freeman, 1979).

(5) $I = I^* + w(T - L - S) = X + P_a.a + P_b.b$

where, P_a = Price of averting activities, P_b = Price of adaptive (medical) activities, I* = Non-wage income, X= Expenditure on other goods and T is Total Time. Time Constraint is T – L – S(c, a, b) = 0.

To get the health impact of a change in arsenic concentration, **c**, in drinking water, we take the total derivative of the health production function:

$$(6) \quad \frac{ds}{dc} = \frac{\partial s}{\partial a^*}\frac{\partial a^*}{\partial c} + \frac{\partial s}{\partial b^*}\frac{\partial b^*}{\partial c} + \frac{\partial s}{\partial c}$$

Equation (6) can be rearranged as follows:

$$(7) \quad \frac{\partial s}{\partial c} = \frac{ds}{dc} - \frac{\partial s}{\partial a^*}\frac{\partial a^*}{\partial c} + \frac{\partial s}{\partial b^*}\frac{\partial b^*}{\partial c}$$

where, a* and b* are the optimal values of averting and adaptive actions.

(8) $a = a(w, P_b, P_a, c, I^*, h, e)$

(9) $b = b(w, P_b, P_a, c, I^*, h, e)$

These optimal values are obtained by maximizing the utility function subject to the constraint (5) (Freeman, 1979). The first order conditions with respect to change in arsenic concentration **c,** (Freeman, 1978; Murty, et al., 2003) can be combined with (7) to show that:

$$(10) \quad W_c = w\frac{\partial s}{\partial c} + P_b\frac{\partial b^*}{\partial c} + P_a\frac{\partial a^*}{\partial c} - \frac{\frac{\partial u}{\partial s}}{l}\frac{\partial s}{\partial c}$$

Expression (10) says that MWTP (*Wc*) for health improvements related to reductions in arsenic concentration, **c**, is the sum of the observable reductions in the wage cost of illness, medical expenditure, averting activities and the monetary equivalent of the disutility of illness. The term $w\frac{\partial s}{\partial c}$ includes both actual and lost wages and lost leisure time valued at the wage rate.

To estimate equation (10) we estimate the health production function (4), and demand functions for a* and b* represented by (8 and 9) as a system of simultaneous equations. This requires information on a) expenditure on adaptation such as medical expenditure, b) wage loss due to sickness, c) averting expenditure such as money or labour time spent for fetching water, d) the socio-economic information on households, and e) information on arsenic contamination in sources of drinking water.

Ideally, it is best to estimate this system of equations using individual-level information. However, in practice it is difficult to get individual-level information especially on averting and medical expenditure because these are often household-level decisions in rural families and avertive expenditure in particular may be indivisible at the individual level. Consequently, several studies on the health production function have used household-level information after controlling for family size in the estimation (Murty, *et al.*, 2003; Dasgupta, 2006). This is the approach we take. Another practical change that we make in the empirical model is in the estimation of the avertive and adaptive demand equations. Because it is hard to assign prices to such actions, these equations are estimated with left-hand side variables reflecting expenditure.

III. Sample Selection and Data Collection

The data for this study is based on a household-level survey of 473 households carried out in the state of West Bengal during 2002-2003. As the first step towards selection of the representative sample, we narrowed down the scope of our survey from a total of 18 districts to 8 districts that have arsenic-affected blocks in them. We expect the averting and adaptation behaviour of the households to vary with the concentration level. Thus, we identified the highest and lowest-level of arsenic concentration across the 8 affected districts. Out of 8 districts we observed that North 24 Parganas has the largest number of arsenic-affected blocks across all districts in West Bengal and has the maximum range of variation in concentration level of arsenic in ground water (3370 μg/l to 51 μg/l levels). These also reflect the maximum and minimum levels for the state. Thus North 24 Parganas was identified for conducting the survey.

To arrive at the household-level units from the districts of 24 Parganas, we followed several steps. The first was to identify blocks (Appendix 3) and then villages with habitations that had the highest range of concentration variation. We arranged the blocks in a descending order of maximum arsenic concentration across all habitations. We took 7 out of 14 blocks with concentration levels greater than 500 μg/l and one out of 6 blocks with concentration levels less than 500μg/l in order to get the maximum variation in concentration levels.

At the next stage, while selecting the villages in the blocks we followed the same procedure as block selection, using village-level concentration information. A control village--Midnapore--which is arsenic free was also chosen. Table 1 shows the number of villages that have been chosen from each block. The survey was planned in such a way that it would cover at least one-third of the habitations. We covered a little less than 50% of the villages but a little more than 50% of the habitations. [4]

Table 20: Study Sites

Sl No	Block	Max conc. (mg/l)	No. of surveyed villages	No. of habitations surveyed	No. of households surveyed
1	Amdanga	3370	1	1	14

[4] The lowest administrative unit for which concentration level is available is the 'habitations' in the villages. Habitations are a cluster of houses forming a residential neighbourhood.

2	Habra II	1945	9	33	88
3	Deganga	1600	13	54	107
4	Baduria	1250	10	59	111
5	Haroa	1060	8	29	85
6	Gaighata	800	7	23	46
7	Habra I	650	1	4	9
8	Barasat	330	1	6	13
			50	209	473
Control	Midnapore		1		50

Source: Public Health Engineering Department (PHED)

In the eight selected blocks, there are 278 villages with arsenic concentration much above the safe limit (50 μg/l). The villages together have 649 tube wells[2] for which arsenic concentration measures are recorded by the Public Health Engineering Department (PHED). Villagers have been made aware of wells with safe drinking water. Tube wells marked with red were identified as unsafe.

Household selection was done through random sampling. Surveyors visited all chosen habitations and identified the shallow tube wells for which concentration levels are reported. They listed the households in the command area of each water source and randomly selected the number of households that they would interview. The number of households surveyed in each command area varied depending on the size of the command area.

The questionnaire which has been used for household interviews is divided into eight sections (see Appendix). An attempt was made to elicit individual-level as well as household-level information. The first section deals with socio-economic details, including basic income-expenditure data. Sections two to four deal with the information relating to a household's demand for quality water. The fifth and sixth sections give us the sickness, that is, medical treatment details of family members arising due to both arsenic as well as non-arsenic diseases. The seventh section

[2] a detailed list is available with the author

contains awareness details, including questions on the nature and number of arsenic-related awareness programmes conducted in the neighbourhood.

A key aspect of the survey was to elicit arsenic disease related information through both direct questioning of the households and the observations of the surveyors who had undergone preliminary training at an Arsenic clinic in Kolkata. In the study area, households were exposed to arsenic-awareness campaigns. Many also knew about their diseases because of visits to arsenic clinics. From field-level observation we identified seven categories of arsenic-related diseases: *melanosis*, *keratosis*, ulcer, vascular disease, lung problem, *polyneuropathy*, and *arsenicosis*. It was observed furthermore that a large percentage of households suffered from *gastroenteritis* and occasional bouts of *diarrhea* and dysentery. To check whether these diseases were also a fallout of prolonged exposure to arsenic above the safe limit of 50 µg/l, a control village with similar socio-economic and demographic features but within the safe limit of arsenic concentration was surveyed. It was found that diarrheal diseases were equally rampant in the arsenic-free area. Moreover, medical practitioners informed us that there is no substantive evidence of a positive correlation between high levels of arsenic concentration in drinking water and *gastroenteric* malfunctions. In the questionnaire, separate questions were posed on arsenic-related as opposed to non-arsenic related diseases.

IV. Households in the Study Area

Socio-economic and demographic features of the surveyed households are given in Table 2. The households have been classified by income categories. The lowest income category with households having monthly income levels equal to or less than Rs 2000 represents the BPL (below poverty line category) followed by the middle and higher income categories .

Table 21: Socio-economic Status of the Surveyed Households

Income Group	Monthly Income Range in Rs.	Percentage of Households	Average Educational Attainment (years of schooling)	Occupational Structure		
				Percentage of Agricultural Households	Percentage of Non-Agricultural Households	Percentage of Both
I	Low Income Group (0-2000)	37.47%	4.11	46.51%	36.05%	17.44%
II	Middle Income Group (2000-6000)	52.51%	4.5	36.51%	33.61%	29.88%
III	High Income Group (6000&above)	10.02%	8.05	8.70%	52.17%	39.13%

Source: Field Survey

The majority (53 %) of households interviewed reported income varying between Rs 2000 and Rs 6000 with 38% of households in the BPL category while 10.02% were in the higher income group. This is comparable to the state-wide income distribution pattern.[5] Educational attainments rise with income level. The low-income group has the highest percentage of households engaged in agricultural activities whereas the high-income group has the highest percentage of families engaged in non-agricultural activities. The middle-income families on the other hand are found to engage in both agricultural and non-agricultural activities in almost equal proportions.

[5] As per government of India estimates, the percentage of rural population living below the poverty line in West Bengal has fallen from 73.16 in 1973-74 to 31.85 per cent in 1999-2000 (Planning Commission, 2002).

Table 3 shows the maximum and minimum concentration levels of arsenic at the block level and the percentage of the population of each block accessing drinking water from arsenic-free sources. Table 4 provides a number of other details by income class. While the proportion of users of arsenic-free water is almost the same (80%, Table 4) for lower and middle income class households, it is higher (90%) for the upper income class. The lower income households suffer the most from both arsenic and non-arsenic diseases, but have less ability to spend on the maintenance of health as reflected through relatively lower medical expenditure and the distance-travelled for accessing health services. The poor also have a higher number of sick days on average. The majority of the households are aware that the quality of water they are using is the main cause of arsenic-related diseases.

Table 22: Households Currently Using Arsenic-Free So urces of Water for Drinking

Sl no.	Blocks	Maximum Arsenic Concentration (µg/l)	Minimum Arsenic Concentration (µg/l)	Percentage of household using arsenic free water
1	Amdanga	3370	51	70%
2	Habra 2	1945	51	72.33%
3	Deganga	1600	51	64.86%
4	Baduria	1250	55	95.29%
5	Haroa	1060	52	50.00%
6	Gaighata	800	54	53.85%
7	Habra 1	650	57	77.78%
8	Barasat	330	51	30.84%

Source: Field Survey

From the random sample of 473 households with a total number of 2432 individual members of all age groups, a total of 871 (36% approx.) members reported that they suffered from some kind of disease over the recall period of one year while only 115 members reported suffering from arsenic-related disease.[6] This means that 4.7% of the sample households experience arsenic-related diseases while 13% of the households reporting any kind of sickness suffer from arsenic-related diseases. Extrapolating from this information based on the random sample survey, it could be said that the chances of an individual living in affected areas to be affected by arsenic-related disease are 0.047 while those of a diseased person suffering from arsenic-related disease are 0.13.

Table 23 : Total Medical Expenditure

Characteristics/Income Range	Low Income (0-2000)	Middle Income (2000-6000)	High Income (6000 & above)
% using arsenic-free water	80	80	90
Average total years of schooling	17	24	49
% of monthly expenditure on food	76	75	69
% of households suffering from Arsenic Diseases	21%	7%	5%
% of households suffering from Non-Arsenic diseases	100%	72%	98%

[6] The survey identified the most prevalent diseases related to arsenic of the households in the surveyed areas .The list of diseases in the questionnaire separated out arsenic-related diseases from non- arsenic diseases.

Average distance travelled to collect water in km.	0.18	0.11	0.13
Average time spent per day in minutes	19	17	22
% of households considering arsenic contamination as major cause of health effects	46	52	47
Average number of sick (including all kinds of sickness) days in a month	9.5	7.8	7.7
Average per capita medicine exp for Non-Arsenic Diseases (Rs/month)	0.95	1.5	13.38
Average per capita expenditure on medicine for Arsenic Diseases (Rs/month)	1.58	12.96	29.17
Average time spent (in minutes/month) by a household to visit hospital for Non-Arsenic Disease	27.84	37.01	71.68
Average time spent (in minutes/month) by a household to visit hospital for Arsenic-related Disease	33.07	47.41	2.50
Average distance travelled to medical facility for Non-Arsenic Disease (km/month)	2.32	6.00	15.94
Average distance travelled to visit medical facility for Arsenic Disease (km/month)	6.95	11.88	18.75

Source: Field Survey

Table 4 shows that 21% of arsenic-affected households out of the total households surveyed are in the lower income group. However, if we consider the total number of households with arsenic patients, 63% are from the lower income group while 33% and 4% respectively are from the middle and higher income groups. Household responses show that on average a sick person suffering from an arsenic-related disease works for 2.73 hours compared to a healthy person who works beyond eight hours per day.

Given the fact that the arsenic-affected areas are primarily rural areas with low average educational levels, it becomes imperative on the part of the local as well as the state-level government bodies to sensitize the population about the possible adverse effects of arsenic contamination. From the household responses, we found that it was only after the year 2000 that the problem of arsenic-contaminated water has been taken seriously at the governmental level and by the non-governmental organizations (NGOs). Our survey reveals that it is the NGOs that are more actively spreading awareness of the problem. The awareness programmes have made the people aware of the health effects of drinking arsenic-contaminated water and possible preventive methods. While the NGOs have conducted a larger number of awareness programmes, the government of West Bengal has concentrated more on infrastructure-building through the digging of deep tube wells, installation of arsenic removal plants (ARP), and the setting up of arsenic treatment clinics.

Survey findings reveal that in West Bengal the Government is the major supplier of good quality water though there is a notable private involvement. Private ownership is higher when it comes to shallow tube wells and ponds. Since all, except those privately-owned, aims at making water supply systems available for public use, people of all income groups have access to these facilities. A total of 89% households depend on the government-provided water supply which is arsenic free. 37% of households resort to privately owned sources for uses other than drinking. 2% of the population use NGO-provided sources. Among the numerous sources of water, such as arsenic removal plants, deep tube wells, dug-wells, community owned filters, shallow tube wells, ponds, etc., it is the deep tube well which forms the primary source of water use currently although approximately five years back it was the shallow tube well which was the main source of water in rural areas when private agencies were the primary suppliers of water. Over the years, dependence on private agencies for sources of water has decreased while government has assumed a lead role. However, while the former was most vulnerable to arsenic contamination, the latter is at a higher risk as far as bacterial or faecal contamination is concerned. Table 5 shows the proportion of investment technology-wise by the Government and other institutions in providing a rural water supply.

Table 24 : Percentage of Capital Stock Supplied by Various Institutions

Sl no		Total number	Government	Privately-owned	Owned by cluster of houses	NGO
1	Arsenic Removal Plants	19	84%	5%		11%
2	Deep tube well	308	98%	1%		1%
3	Community owned filter	1				100%
4	Shallow tube well	211	36%	61%	3%	
5	Pond	47	17%	77%	4%	

Source: Field Survey

V. Empirical Estimation of Production and Demand Functions

As stated in Section II, we attempt to estimate the welfare gain by the households from arsenic removal through the estimation of MWTP or the avoided cost of wage loss due to sickness, adaptation cost through medical expenditure, and averting cost. We estimate a system of simultaneous equations consisting of three equations in three endogenous variables: sick days, medical expenditure, and averting expenditure.

The system of simultaneous equations with three equations in three endogenous variables is:

$$\ln Y_1 = \sum \beta_{1j} \ln X_{1j} + \sum \beta_{1j} \ln Y_{1j} + u_1 \text{........(11)}$$
$$\ln Y_2 = \sum \beta_{2j} \ln X_{2j} + \sum \beta_{2j} \ln Y_{2j} + u_2 \text{......(12)}$$
$$\ln Y_3 = \sum \beta_{3j} \ln X_{3j} + \sum \beta_{3j} \ln Y_{3j} + u_3 \text{......(13)}$$

where Y and X show the vector of endogenous and exogenous variables appearing in i^{th} (=1, 2, 3) equation. The explanatory variables in Y and X vector are shown by j. We take the double log form of the equations based on our assumption (mentioned in Section II) of non-linearity of the underlying functions. Equation (11) represents the household health production function expressing the health status given in terms of number of sick days in a household. Equations 12 and 13 represent household demand for adaptive expenditure and averting activity.

Table 6 provides the list of variables (j in equations 11-13) used in estimation of the three equations. Each of the equations is expressed as a function of exogenous and instrumental variables representing household and local water quality characteristics listed in Table 6. We estimate the parameters for the three income groups by pooling the data across the three income groups (separate estimates for the three income groups are shown in the Appendix) using appropriate dummy variables. The estimation has been done using the log linear version of the equations. Since endogenous variables appear among the explanatory variables set, we have made use of the Three Stage Least Square (3SLS) estimation procedure.

Table 25: Equations and Variable Descriptions

Endogenous Variables	**Represented**	**Appears in Equations/Models with Expected Signs**			
	by Variable/				
	(Equation)	**Pooled**	**Income group I**	**Income group II**	**Income group III**
Number of sick days in a month	msickd (EQ1)	EQ1	EQ1	EQ1	EQ1
Monthly Household Medical Expenditure	mmedexp (EQ2)	EQ2	EQ2	EQ2	EQ2
Monthly Averting Expenditure	avert (EQ3)	EQ3	EQ3	EQ3	EQ3
Explanatory Variables					
Endogenous variables					
Number of sick days in a month	msickd	EQ2 (+), EQ3 (+)	EQ2 (+), EQ3 (+)	EQ2 (+), EQ3 (+)	EQ2 (+), EQ3 (+)
Monthly Household Medical Expenditure	mmedexp	EQ3 (-)	EQ3 (-)	EQ3 (-)	EQ3 (-)
Monthly Averting Expenditure	avert	EQ1(+), EQ2 (-)	EQ1(+), EQ2 (-)	EQ1(+), EQ2 (-)	EQ1(+), EQ2 (-)
Exogenous Variables /Instruments					
Number of persons sick in a household	nopersick	EQ1(+)	EQ1(+)		
Total age of the members in a household	tage	EQ1(+), EQ2(+)	EQ1(+), EQ2(+)	EQ1(+), EQ2(+)	EQ1(+), EQ2(+)
Monthly household income (ÿg)			EQ3(+)		
Monthly household expenditure on food	mexpf	EQ1 (-),EQ2 (-)	EQ2 (-)	EQ2 (-)	EQ2 (-)
Health Stock Index	nonarsd	EQ1(+), EQ2(+)	EQ1(+), EQ2(+)	EQ1(+), EQ2(+)	EQ1(+), EQ2(+)
Family size	fz	EQ1(?)	EQ1(?)	EQ1(?)	EQ1(?)
Household's exposure to arsenic	hexpa	EQ1 (+), EQ2 (+), EQ3 (+)	EQ1 (+), EQ2 (+), EQ3 (+)	EQ1 (+), EQ2 (+), EQ3 (+)	EQ1 (+), EQ2 (+), EQ3 (+)
Distance travelled to fetch arsenic free water	dist	EQ1, EQ2, EQ3	EQ1, EQ2, EQ3	EQ1, EQ2, EQ3	EQ1, EQ2, EQ3
Household Time spent for fetching	time	EQ1, EQ2, EQ3	EQ1, EQ2, EQ3	EQ1, EQ2, EQ3	EQ1, EQ2, EQ3
Arsenic-free water					

Agriculture as primary source of income	agr	EQ3(?)		EQ3(?)	EQ3(?)
Water contamination as major cause of disease	majcau	EQ2 (+), EQ3(+)	EQ2(+)	EQ2 (+), EQ3(+)	EQ2 (+), EQ3(+)
Dummy for income group 1	Inccode1	EQ1(?), EQ2(?), EQ3(?)			
Dummy for income group II	Inccode2	EQ1(?), EQ2(?), EQ3(?)			

We briefly describe below the construction of selected variables used in the estimation.

Sick days in the households (msickd**)**

The number of days per month spent sick by the members in each household is used as a measure of health status. The cause of sickness may be arsenic-related diseases, non-arsenic related diseases, or both. This information was obtained by directly asking the respondent about the total days of sickness in the recall period of one year for each adult and child member in that household. Sick days are converted to per month to be consistent across all variables.

Medical Expenditures (mmedexp)

This refers to household total medical expenditure for all the members for all kinds of diseases, both arsenic and non-arsenic. It was difficult to obtain separate medical expenditures by disease during the survey.

Averting Activities (avert)

Avertive activities are defined as the time spent by a household each day to collect arsenic-free water. Households were asked questions regarding the approximate distance they travel and the time spent for collection of arsenic-free water. On the basis of information on hours per day spent on collecting water, we find that the average household spends about 7 working days per month on water collection. The averting activity is converted from physical units of number of days and distance travelled to monetary values. The distance travelled is converted into units of time and monetized using the wage rate for female members.

Household Exposure Index (hexpa)

The Household Exposure Index is arrived at by taking the product of arsenic concentration level (μg/l) for the habitation and water consumed by each household per month. The household level water consumption varies by gender and age. We have considered water intake daily by adult male, female and children of 6, 4, and 2 litres respectively. The Arsenic Concentration Index for each habitation is available from the PHED database. The product of water consumed and the arsenic concentration level in the water is aggregated over all members in the family.

Health Stock Index (nonarsd)

The Index for Health Stock, which measures the health capital of the household, is the weighted sum of the number of non-arsenic diseases that family members have suffered over the recall period of six months. Weights are given by the ranks to show the relative expensiveness of the disease. For example, chronic diseases such as asthma have a higher numeric rank compared to diseases such as flu. The higher the value, the worse is the health stock.

Education (totedu**)**

The literacy level of households is the total number of years of schooling that the family members have had which shows the household-wise social capital as an index of awareness level of the households. This has been constructed from member-wise details of educational attainment.

Major Cause (majcau)

This is a binary variable reflecting the awareness level of the respondent of the household about the arsenic contamination in the water used and its health effects.

Number of Persons Sick in Households (nopersick)

This gives a count of persons sick in the households per month. This variable is included as a scale factor since we use the total number of sick days as another explanatory variable.

VI. Results and Discussions

Parametric estimates of the structural equations (11), (12) and (13) using 3SLS estimation procedure are provided in Table 7 for the data set pooled over all income groups. (The Appendix tables A1-A.3 report results for the three income groups separately).

The results in Table 7 show that the number of sick days increases with household exposure to arsenic and decreases with increasing medical expenditure. However, the coefficients are not statistically significant. Averting activities show a significant but positive relation to sick days which appears to have a perverse sign. It needs to be mentioned that the sick days include all types of disease and not arsenic-related diseases exclusively. Hence, averting activities targeted at getting arsenic-free water may not show a reduction in the number of sick days. However, the causality of the impact of sick days on averting behaviour (equation three) shows the correct relation. It is expected that households will adopt more averting activities if they experience more sickness.

The second equation explains the determinants of adaptive behaviour represented by medical expenditure. Medical expenses rise as hypothesised with household exposure to arsenic and number of sick days and decrease if averting activities increase. All the relevant coefficients are statistically significant.

Equation 3 shows that averting activity increases and is statistically significant if household exposure to arsenic increases.

Table 26: Parameter Estimates of Model for Pooled Data

Model/*Equation*/			
Variables			
Pool			

EQ1 (sick days)	expected sign	parameter value	t-value
constant	?	-19.43	-1.57*
nopersick	+	0.86	4.19***
avert	-	0.27	2.34***
tage	+	7.23	1.87**
mexpf	-	-0.03	-0.12
nonarsd	+	2.03	1.77
Fz	?	-6.62	-1.62*
hexpa	+	1.23	1.08
inccode1	?	-1.39	-0.88
inccode2	?	1.53	0.44
R^2	0.41		
EQ2 (medical expenditures)			
constant	?	-7.53	-1.94***
msickd	+	0.75	6.66***
avert	-	-0.58	-7.19***
mexpf	+	0.07	0.46
tage	+	-0.41	-0.36
nonarsd	+	0.69	0.92
majcau	+	1.04	3.15***
hexpa	+	1.30	3.23***
inccode1	?	4.57	2.40***
inccode2	?	5.15	1.54*
R^2	0.47		
EQ3(avertive expenditures)			
constant	?	-10.52	-2.41***
msickd	+	0.79	3.77***
mmedexp	-	-1.07	-4.28***
agr	?	-0.38	-0.92
majcau	+	1.18	2.30***
hexpa	+	1.38	2.26***
inccode1	?	4.57	2.40***
inccode2	?	5.15	1.54*
R^2	0.0074		

Source: Author's Estimates

***significant at 1% level, ** significant at 5% level and * significant at 10% level

VII. Estimating Welfare Gain from Arsenic Removal

Table 7 presents estimates of the components of the equation 10 (Section II). Given the variable descriptions and their constructions in Table 6 and corresponding text, equation (10) can be rewritten as:

(14)

$$Wc = MWTP = w \left[\frac{\partial(sickdays)}{\partial(exposure\,to\,arsenic)} + \frac{\partial(Medical\,expenses)}{\partial(exposure\,to\,arsenic)} + \frac{\partial(Averting\,activity)}{\partial(exposure\,to\,arsenic)} \right]$$

$$Wc = MWTP = w \left[\frac{\partial(msickd)}{\partial(hexpa)} + \frac{\partial(mmed\exp)}{\partial(hexpa)} + \frac{\partial(avert)}{\partial(hexpa)} \right]$$

The MWTP is estimated for all income groups (pooled data) and the three different income groups separately and are presented in Table 8. The pooled results use parameter estimates from Table 7. The results for the different income groups are based on separate regressions, which are presented in the Appendix (A1-A3).

In order to calculate the MWTP in Table 8, we adjust the estimated parameters in Table 7 since these estimates are in log-linear formulation. Thus, the reported average MWTP s in the table 8 are arrived at by adjusting each of the coefficients at mean values of the variables. In addition, the first coefficient is multiplied by the wage rate /month to arrive at the final MWTP values.

Some of the parameter estimates used in (14) to arrive at the welfare calculation in Table 8 are statistically insignificant even at the 10% level of significance (Tables 7, A1-A3). Recent studies by others such as Murty, *et al.*, (2003) and Gupta (2006) have ignored the statistical significance of coefficients in estimating welfare gain and loss. However, in Table 8 we report estimates of welfare gains when the coefficient values are set at their actual estimated values and also set at zero if they are not significantly different from zero.

The first coefficient in (14), i.e., the change in sick days with changing arsenic concentration is statistically insignificant and so we assume its value to be zero. Based on this, our estimates suggest that the welfare gain from a reduction in 1µg per litre of arsenic for the pooled sample is Rs 0.49 per household per month.

If the arsenic concentration is reduced to the safe limit of 50 μg/l, the benefits to each household is Rs 297 per month while the annual household gain is Rs 3573. The same benefits are Rs 161 per month and Rs 1934 per year if the arsenic concentration is reduced by half of what it is right now.

These figures need to be interpreted with some caution. We arrive at these values of welfare gain by proportionally scaling up econometric estimates of the gain from a marginal (1 unit) change. It is possible that this linear scaling-up is incorrect, but with no other information, we assume that this relationship between dose and medical and avertive expenditure holds at different levels of doses.

We also look at the welfare gains for different income groups by estimating the equations separately for poor, middle-income, and rich groups. We find that for the high income group all the three coefficients used in (14) are statistically insignificant, which implies that the minimum MWTP is close to zero. This may be because the higher income group is already less adversely affected by arsenic and will gain relatively little from arsenic removal. However, we also estimate 95% confidence intervals to show a range within which the welfare gains may fall in Appendix A4.

Table 27: Household Characteristics and Estimates of Welfare Gain

	Income Groups			
Average Characteristics	Income<=2000	Income >2000 <=60000	income >6000	Pooled
Income/ month (Rs) w	1431.98	3389.53	10906.83	3731.16
Family size (Number)	4.45	5.51	6.73	5.27
Sick days/month (number)	9.50	7.82	7.75	8.16
Medical expenditure/month (Rs)*	205.58	297.68	168.21	234.53
Averting expenditure/month (Rs)	13.02	11.36	14.46	12.08
Concentration of arsenic (μg/l)	688.90	627.44	610.74	655.61
Welfare gain (MWTP, *Wc*)				

Monthly welfare gain from reduction of arsenic concentration by **1 μg/l** (Rs)	0.56 (0.52)	1.02 (0.77)	3.65 (0.00)	2.39 (0.49)
Monthly welfare gain from reduction of arsenic concentration by **half of the current level** (Rs)**	192.69 (179.23)	319.52 (242.49)	1115.73 (0.00)	784.81 (161.18)
Monthly welfare gain from reduction of arsenic concentration **to safe limit of 50 μg/l** (Rs)**	357.42 (335.52)	588.12 (446.35)	2048.77 (0.00)	1449.91 (297.77)
Annual welfare gain from reduction of arsenic concentration by **1 μg/l** (Rs)	6.71 (6.3)	12.00(9.28)	43.84 (0.00)	28.73 (5.90)
Annual welfare gain from reduction of arsenic concentration by **half of the current level** (Rs)**	2312.69 (2150.8)	3834.27 (2909.92)	13388.73 (0.00)	9417.69 (1934.12)
Annual welfare gain from reduction of arsenic concentration **to safe limit of 50 μg/l** (Rs)**	4289.8(3402.27)	7057.44(5356.15)	24585.25 (0.00)	17398.89 (3573.23)

Note: Figures within brackets show the results if values of the parameters that are statistically insignificant are taken as zero.

*This includes expenditures made on medicine (Table 4) and other non-medical costs (e.g., doctor's fee, hospital visitation expenses, hospital transfer expenditure, etc.).

**The scaling factor used is the difference between the observed magnitude of concentration exposure and the desired target. For example, if the observed value of concentration exposure is 600μg/l then a scaling factor of 550 (=600-50) is used to estimate the welfare gain to reduce arsenic concentration level to its safe limit.

Source: Author's Estimates

It is useful to compare the findings of this study with recent estimates of willingness-to-pay to reduce arsenic in Bangladesh (Ahmad, *et al.*, 2002). While our study shows that averting expenditure ranges from Rs 11.36-14.46 per month per household in West Bengal, in Bangladesh the comparable values are Taka 12.6-16.3 per month. However, the MWTP from our revealed preference study which takes into consideration all three components--sick days, medical expenditure and averting expenditure--is much higher compared to the stated preference WTP value obtained by Ahmad, *et al.,* (2002).

The annual welfare gain estimated for arsenic removal is higher than the estimated gains for air and water pollution removal (Murty, *et al.,* Jalan, *et al.,* 2003, Gupta 2006). The reason might be attributed to the fact that Gupta's study does not include averting expenditure while Jalan, *et al.,*'s study considers averting expenditure only and Murty, *et al.*'s study has a lower estimate of the number of sick days (two days per month) compared to the present study (eight days per month). Arsenic-affected households report a relatively larger number of sick days per month compared to other kinds of pollution-induced sickness which is not counter factual. This may be partly because the study area has a very high level of arsenic concentration with a maximum concentration of up to 3370 µg/l (see Table 1).

If we consider the fact that the chances of getting an arsenic-related disease in an arsenic-prone zone is 0.047 while the total population size is 7.2 million for the district, then the total number of people with the likelihood of arsenic-related sickness is 3,38, 400. The total annual welfare gain to households (considering the household size in the pooled sample in Table 8 and the likely number of arsenic-affected people) from bringing down the arsenic concentration to a safe limit of 50µg/l in the district will therefore be Rs 229 million.

VIII. Conclusions and Policy Implications

The study aimed to assess the economic costs of arsenic-related health problems. The scope is limited to one district in West Bengal but the results are comparable with other studies. It is useful to know from this study that the chance of a person living in North 24 Parganas district of West Bengal getting an arsenic-related disease is quite low at 0.047. But if we estimate the cost burden to society in aggregate monetary terms, this works out to Rs 229 million in North 24 Parganas. It is important for policy makers to know that reduction in arsenic concentration in water to the safe limit through technological and policy intervention can generate such large health benefits. The policy relevance of this estimate of the health cost of arsenic contamination is noteworthy because, if guided only by physical measures such as the probability of getting arsenic-related disease, which is low, decision-makers may not feel compelled to act. However, the current research on the monetary valuation of welfare loss shows the kind of value addition that can result from arsenic removal.

A comparison of benefits generated from arsenic removal with the cost associated with supplying filtered piped water justifies investments in an arsenic-free water supply system in arsenic-affected areas. Currently, the cost of supplying filtered piped water by the Kolkata Municipal Corporation to households is approximately Rs 9.44/m^3. Assuming an average consumption of 450 litres per household per day, the full O&M cost recovery would impose a cost burden of Rs 127/-month per household (KMC, 2004). This number is lower than the benefits that accrue from consuming arsenic-free water, which we estimate at Rs 297 per month per household. Further, if we compare the benefit and full cost burden on households for installing deep tube wells, we find that the initial cost can be paid back in a maximum of three years.

However, some shortcomings to this study need to be discussed in order to highlight the scope for further research in this area. The variable actually used to capture mitigating expenditure is the total medical expenditure on all diseases, which includes arsenic-related diseases. Some of the symptoms that are associated with arsenic could have been caused by other diseases as well. To correct this problem, we would need to supplement socio-economic data with information from clinical investigations. We were unable to do this in the current study. Moreover, detailed information on each household member would have allowed for a more careful investigation and an understanding of the disaggregated impacts of arsenic exposure.

The welfare gain estimates from arsenic removal needs further refinement based on a better understanding of how medical and averting expenditure can change when there is a non-marginal change in arsenic concentration. In view of these limitations, the specification and estimation of the health production function can only be taken as a reasonable first approximation that should be improved upon in future studies.

Appendix

Table A 1: Parameter Estimates of Model for Income Group I

Model/ *Equation*/			
Variables			
Income Group I			
EQ1	expected sign	parameter value	t-value
Constant		-9.13	-1.16
Nopersick	+	0.88	3.60*
Avert	-	-0.19	-1.44
Tage	+	4.11	1.47
Nonarsd	+	2.03	1.61***
Fz	?	-2.57	-1.16
Hexpa	+	0.05	0.08
R^2	0.47		
EQ2			
Constant		-11.72	
Msickd	+	0.48	2.71*
Avert	-	0.32	1.92**
Mexpf	-	-0.01	-0.05
Tage	+	0.49	0.20
Nonarsd	+	1.79	1.34
Majcau	+	1.58	3.06*
Hexpa	+	1.74	3.10*
R^2	0.42		
EQ3			
Constant		-10.99	-2.84*
Msickd	+	3.53	2.71*
Mmedexp	-	0.14	1.92**
Totedu	+	0.00	0.02
Hexpa	+	0.25	0.84
Mfinc	+	1.15	5.40*
R^2	0.07		

Source: Author's Estimates

*significant at 1% level of significance
** significant at 5% level of significance
*** significant at 10% level of significance

Table A 2: Parameter Estimates of Model for Income Group II

Model/ *Equation*/			
Variables			
Income Group II			
EQ1	expected sign	parameter value	t-value
Constant	?	-69.88	-2.11*
Avert	-	0.14	0.74
Tage	+	1.23	0.47
Nonarsd	+	5.33	5.09*
Fz	?	-5.13	-1.46
Hexpa	+	0.17	0.23
Mfamexp	+	18.57	2.06*
R^2	0.046		
EQ2			
Constant	?	-6.37	-1.97**
Msickd	+	0.65	4.87*
avert	-	-1.07	-11.26*
mexpf	-	0.16	0.77
tage	+	-0.95	-0.91
nonarsd	+	1.38	1.77**
majcau	+	0.68	1.56***
hexpa	+	1.59	3.20*
R^2	0.46		
EQ3			
constant	?	-3.70	-1.62***
msickd	+	0.55	3.33*
mmedexp	-	-0.64	-3.93*
agr	?	-0.04	-0.19
majcau	+	0.36	1.13
hexpa	+	0.98	2.02*
R^2	0.0059		

Source: Author’s Estimates

*significant at 1% level of significance
** significant at 5% level of significance
*** significant at 10% level of significance

Table A 3: Parameter Estimates of Model for Income Group III

Model/ *Equation*/			
variables			
Income Group III			
EQ1	expected sign	parameter value	t-value
constant	?	-10.87	-0.76
nopersick	+	0.48	1.21
avert	-	0.43	2.45*
tage	+	2.28	0.38
nonarsd	+	3.73	1.26
fz	?	-3.06	-0.49
hexpa	+	0.73	0.72
EQ2	0.60		
constant	?	-2.85	-0.43
msickd	+	1.24	3.94*
avert	-	-0.71	-6.94*
mexpf	?	0.17	0.15
tage	+	-0.01	-0.01
nonarsd	+	-0.43	-0.28
majcau	+	1.04	1.03
hexpa	+	0.94	1.04
EQ3	0.64		
constant	?	-4.51	-0.64
msickd	+	1.69	4.30*
mmedexp	-	-1.45	-5.67*
agr	?	-0.04	-0.07
majcau	+	1.62	1.08
hexpa	+	1.46	1.15
R^2	0.09		

Source: Author's Estimates

*significant at 1% level of significance
** significant at 5% level of significance
*** significant at 10% level of significance

A majority of parameters are significant at varying levels of significance and barring a few all policy relevant parameters have expected signs. The reason may be a very limited variation in the variables.

Appendix A 4: Confidence Interval Estimates of MWTP/Welfare Gain

	Income groups							
	Income<=2000		Income >2000 <=60000		income >6000		Pool	
Welfare gain	**Lower bound**	**Upper bound**	**Lower bound**	**Upper bound**	**Lower bound**	**Upper bound**	**Lower bound**	**Upper bound**
Monthly welfare gain from reduction of arsenic concentration by **1mg/l (Rs)**	-0.26	1.15	0.12	1.92	0.21	7.09	-0.01	4.80
(Point estimate)	0.56 (0.30)		1.02 (0.46)		3.65 (1.66)		2.39 (1.23)	
Monthly welfare gain from reduction of arsenic concentration **to safe limit of 50 mg/l (Rs)**	-46.18	761.01	-30.15	1206.39	-205.96	4303.5	-126.45	3026.27
(Point estimate)	357.42 (205.92)		588.12 (315.45)		2048.77(1089.77)		1449.91 (804.26)	
Annual welfare gain from reduction of arsenic concentration by **1mg/l (Rs)**	-0.32	13.74	1.45	22.99	2.57	85.11	-0.12	57.58
(Point estimate)	6.71(3.58)		12.00 (5.49)		43.84 (19.91)		28.73 (14.72)	
Annual welfare gain from reduction of arsenic concentration **to safe limit of 50 mg/l (Rs)**	-554.21	9132.20	-361.83	14473.76	-2471.54	51642.05	-1517.45	36317.28

(Point estimate)	4289.8(2471.02)	7057.00(3785.35)	24585.25(13077.23)	

Appendix 1 Water Cess Rates

Purpose for which water is consumed	Maximum rate under sub-section (2) of section 3	Maximan rate under sub-section (2A) of section 3
1. Industrial cooling, spraying in mine pits or boiler feed	Five paise per kilo litre	Ten paise per kilo litre
2. Domestic purpose	Two paise per kilo litre	Three paise per kilo litre
3. Processing whereby water gets polluted and the pollutants are (i) easily bio-degradable; or (ii) non toxic; or (iii) both non-toxic and easily bio-degradable	Ten paise per kilo litre	Three paise per kilo litre
4. Processing whereby water gets polluted and the pollutants are; (i) not easily bio-degradable or (ii) toxic; or (iii) both toxic and not easily bio-degradable	Fifteen paise for kilo litre	Thirty paise per kilo litre

Source: CPCB (2006a)

Appendix 2 Marginal Abatement Costs for Mills using Methodology 1

BODB=800(Max)												
Bod	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10	f11	f12
750	0.14	0.50	0.30	2.81	0.98	2.51	0.29	0.15	0.09	0.46	0.59	0.02
500	0.27	0.94	0.57	5.35	1.86	4.78	0.56	0.29	0.17	0.87	1.11	0.03
200	1.14	4.04	2.42	22.89	7.96	20.42	2.39	1.22	0.74	3.72	4.77	0.15
100	3.41	12.13	7.26	68.72	23.90	61.31	7.17	3.67	2.23	11.16	14.31	0.44
50	10.23	36.43	21.81	206.31	71.76	184.07	21.54	11.01	6.71	33.50	42.97	1.33
30	23.01	81.90	49.03	463.85	161.34	413.85	48.42	24.74	15.08	75.31	96.60	2.98
20	43.77	155.79	93.28	882.39	306.91	787.26	92.11	47.07	28.69	143.26	183.76	5.67
10	131.41	467.71	280.03	2649.07	921.40	2363.48	276.52	141.31	86.13	430.08	551.68	17.02

BODB=237.5(Mean)												
Bod	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10	f11	f12
750	0.08	0.27	0.16	1.51	0.53	1.35	0.16	0.08	0.05	0.25	0.32	0.01
500	0.14	0.51	0.30	2.88	1.00	2.57	0.30	0.15	0.09	0.47	0.60	0.02
200	0.61	2.18	1.30	12.32	4.29	10.99	1.29	0.66	0.40	2.00	2.57	0.08
100	1.83	6.53	3.91	36.99	12.87	33.00	3.86	1.97	1.20	6.01	7.70	0.24
50	5.51	19.61	11.74	111.06	38.63	99.08	11.59	5.92	3.61	18.03	23.13	0.71
30	12.39	44.08	26.39	249.68	86.85	222.77	26.06	13.32	8.12	40.54	52.00	1.60
20	23.56	83.86	50.21	474.98	165.21	423.77	49.58	25.34	15.44	77.11	98.92	3.05
10	70.73	251.76	150.74	1425.95	495.98	1272.23	148.85	76.07	46.36	231.51	296.96	9.16

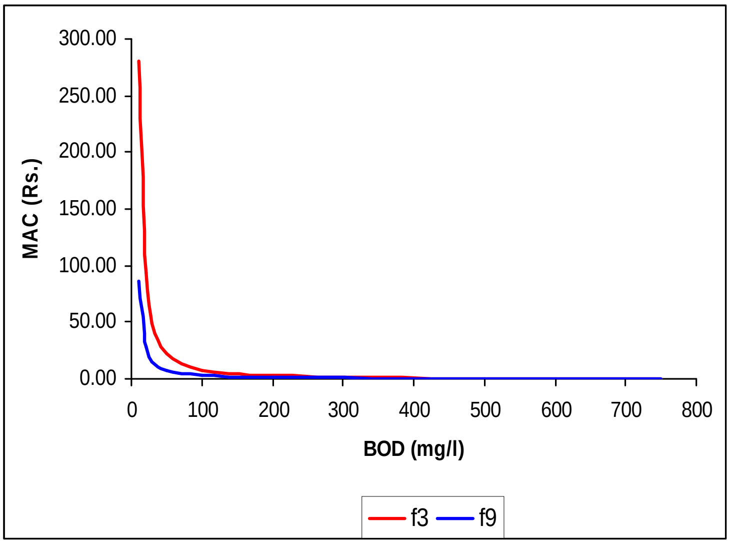
BODB=362.4 (median)												
Bod	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10	f11	f12
800	0.08	0.30	0.18	1.70	0.59	1.51	0.18	0.09	0.06	0.28	0.35	0.01
500	0.18	0.63	0.38	3.57	1.24	3.19	0.37	0.19	0.12	0.58	0.74	0.02
200	0.76	2.70	1.62	15.29	5.32	13.64	1.60	0.82	0.50	2.48	3.18	0.10
100	2.28	8.10	4.85	45.89	15.96	40.94	4.79	2.45	1.49	7.45	9.56	0.29
50	6.83	24.32	14.56	137.76	47.92	122.91	14.38	7.35	4.48	22.37	28.69	0.89
30	15.36	54.69	32.74	309.73	107.73	276.34	32.33	16.52	10.07	50.29	64.50	1.99
20	29.23	104.03	62.29	589.21	204.94	525.69	61.50	31.43	19.16	95.66	122.71	3.79
10	87.75	312.31	186.99	1768.90	615.26	1578.20	184.65	94.36	57.51	287.19	368.38	11.37

Appendix 3: Marginal Abatement Costs for Mills using Methodology 2

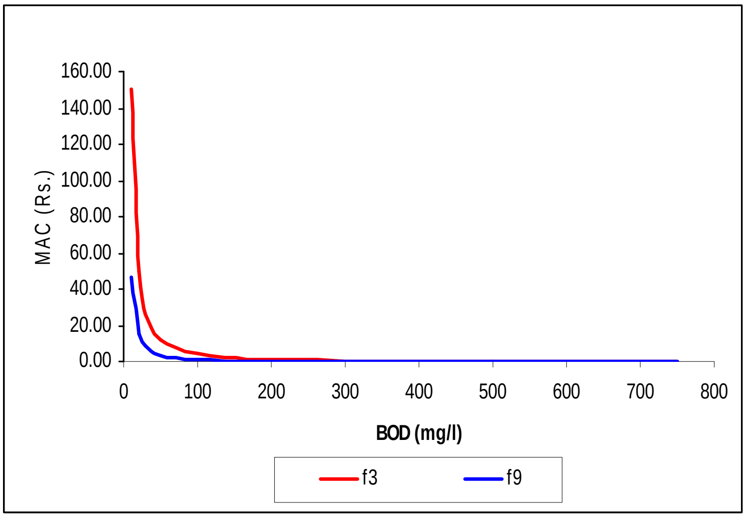
BODB=800												
Bod	f1	f2	f3	f4	f5	f6	f7	f8	f9	F10	f11	f12
800												
500	0.412	1.49	0.887	8.6189	2.9596	7.6791	0.875	0.444	0.27	1.369	1.761	0.0521
200	1.235	4.464	2.656	25.826	8.8681	23.009	2.623	1.329	0.81	4.101	5.277	0.1561
100	3.37	12.18	7.248	70.468	24.198	62.784	7.156	3.627	2.2	11.19	14.4	0.4259
50	9.537	34.47	20.51	199.4	68.472	177.66	20.25	10.26	6.22	31.67	40.74	1.2051
30	20.73	74.95	44.59	433.55	148.87	386.27	44.03	22.32	13.5	68.85	88.58	2.6202
20	38.53	139.3	82.87	805.68	276.66	717.83	81.82	41.47	25.1	127.9	164.6	4.8693
10	111.6	403.3	239.9	2332.7	801.01	2078.3	236.9	120.1	72.7	370.4	476.6	14.098

BODB=237.5(Mean)												
Bod	f1	f2	f3	f4	f5	f6	f7	f8	f9	F10	f11	f12
800												
500												
200	1.479	5.346	3.181	30.926	10.619	27.554	3.141	1.592	0.96	4.911	6.319	0.1869
100	2.291	8.281	4.927	47.903	16.449	42.68	4.865	2.466	1.49	7.607	9.788	0.2895
50	5.826	21.06	12.53	121.81	41.827	108.53	12.37	6.27	3.8	19.34	24.89	0.7362
30	12.27	44.36	26.4	256.62	88.119	228.64	26.06	13.21	8	40.75	52.43	1.5509
20	22.49	81.29	48.37	470.25	161.48	418.98	47.76	24.21	14.7	74.68	96.08	2.8421
10	64.28	232.3	138.2	1343.9	461.49	1197.4	136.5	69.18	41.9	213.4	274.6	8.1224
BODB=362.4 (Median)												
Bod	f1	f2	f3	f4	f5	f6	f7	f8	f9	F10	f11	f12
800												
500												
200	1.077	3.893	2.316	22.52	7.733	20.064	2.287	1.159	0.7	3.576	4.601	0.1361
100	2.527	9.133	5.434	52.832	18.141	47.071	5.365	2.72	1.65	8.39	10.79	0.3193
50	6.833	24.7	14.7	142.88	49.062	127.3	14.51	7.355	4.46	22.69	29.19	0.8635
30	14.64	52.92	31.49	306.1	105.11	272.72	31.09	15.76	9.55	48.61	62.54	1.85
20	27.02	97.67	58.11	564.99	194.01	503.38	57.38	29.08	17.6	89.72	115.4	3.4146
10	77.73	281	167.2	1625.3	558.11	1448.1	165.1	83.66	50.7	258.1	332.1	9.823

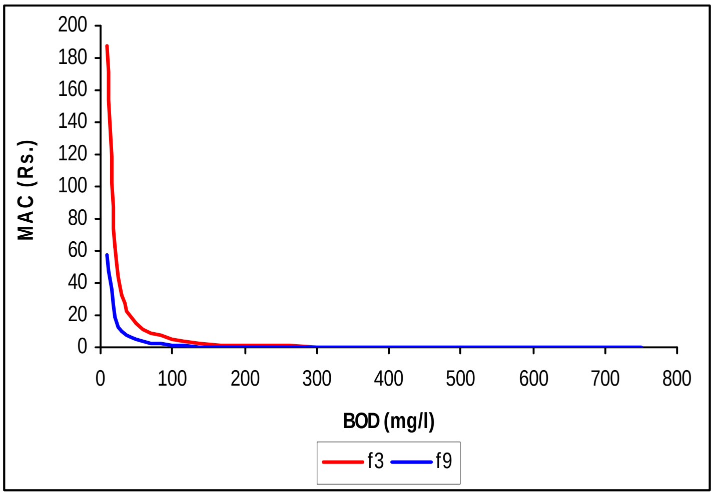
Appendix: 4 Figure: Marginal Abatement Cost Curves for Mill 3 and Mill 9 when BODB = 800



Appendix 5 Figure Marginal Abatement Cost Curves for Mill 3 and Mill 9 when BODB = 237.5



Appendix 6 Figure: Marginal Abatement Cost Curves for Mill 3 and Mill 9 when BODB = 362.4



Chapter IV

Air Account

Air Account: Flow

I. Case study of Kolkata Municipal corporation area (KMC)

For Air account calculations we have considered the physical parameters like background concentrations and standards to assess the flow of pollutants and source apportionment. The detailed analysis can be done based on data availability for KMC area using the existing maps of monitoring stations distribution and map of economic activities. This can guide us as to what can be scaled up for complete air account for West Bengal. For the same study area we have assessed the damage cost assessment also which is presented in the next section.

Table 1 Background concentrations of local pollutants

Pollutants	Background Concentrations	Range or level of Background concentrations	Background concentration for West Bengal (level reported on bandh day)	Standard (residential)
SO2	Data comes from North-West Scotland. No major industrial activity in this region prevailing. South westerly winds are unlikely to carry high pollution load. Review Group on Acid rain (RGAR,90) 1ppbv SO2 for this region. UK Harwell Trajectory Model data also agrees with this data (0-2 range)	0-2ppbv3	4µg/m3(dec) 1.5271ppbv3 2 µg/m3(june) 0.76 ppbv3	80 µg/m3 30.54 ppbv3
NOX	Data source same as before 2 ppbv NO2	2 ppbv NO2	35µg/m3(dec) 26 µg/m3(june) 18.6 ppbv	80 µg/m3 42.52 ppbv
PM10	Difficult to predict because of the diverse sources of particulate of natural origin. Components are Ammonium (6%), Nitrate(5%), Sulphate(18%), Chloride(6%), Base cations(6%), carbonaceous matter(37%), insoluble minerals(22%). 70% of the total emission arises from human activity. Natural background concentration of PM10 is 10µg/m3(5-15 range)	16-24 µg/m3	SPM: 248 µg/m3(dec) 70 µg/m3(june)	200 µg/m3: SPM RPM 100
Ozone	Background concentration vary with altitude, sunlight and other climatic conditions. Annual mean background concentration assumed here were between 10 and 20 ppbv (16-24 range)			

Unit of conversion:

from mg/m^3 to ppmv:

ppmv = $(mg/m^3)(273.15 + °C) / (12.187)(MW)$

from ppmv to mg/m^3

$mg/m^3 = (ppmv)(12.187)(MW) / (273.15 + °C)$

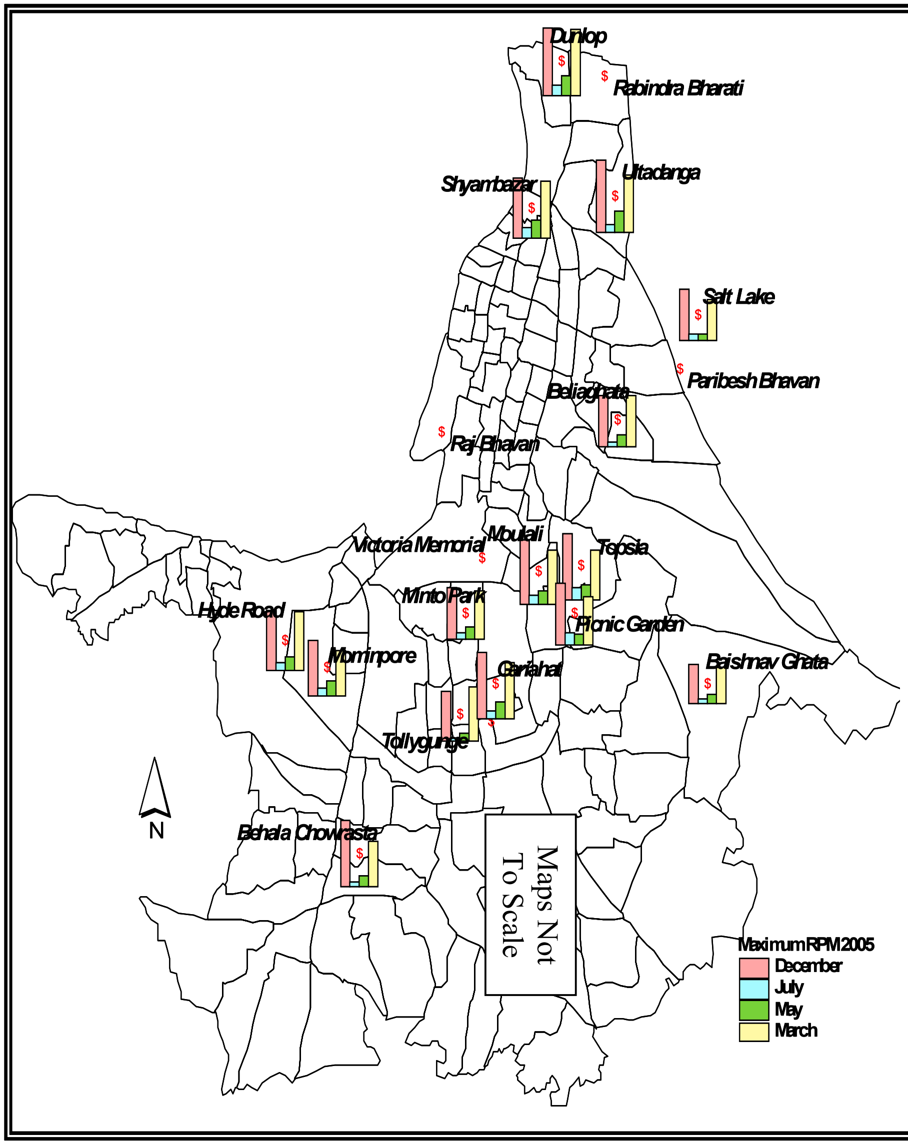
II. Data source

1. For physical account we have used the West Bengal Pollution Control Board data
2. For valuation we have used field survey data
3. For monetary account we have tried to use damage cost approach.

III. Physical account

The air quality monitoring provides daily values of the major pollutants in 19 monitoring stations in the KMC area. The data has been collected for 2004, 2005 .The main objective of this study to set reduction in the concentrations of the major pollutants. Maps and tables show the monitoring stations and the corresponding physical estimates of the air pollution parameters. These flow parameters combined with information in Table 1 give us additional quality change of local air quality

RPM



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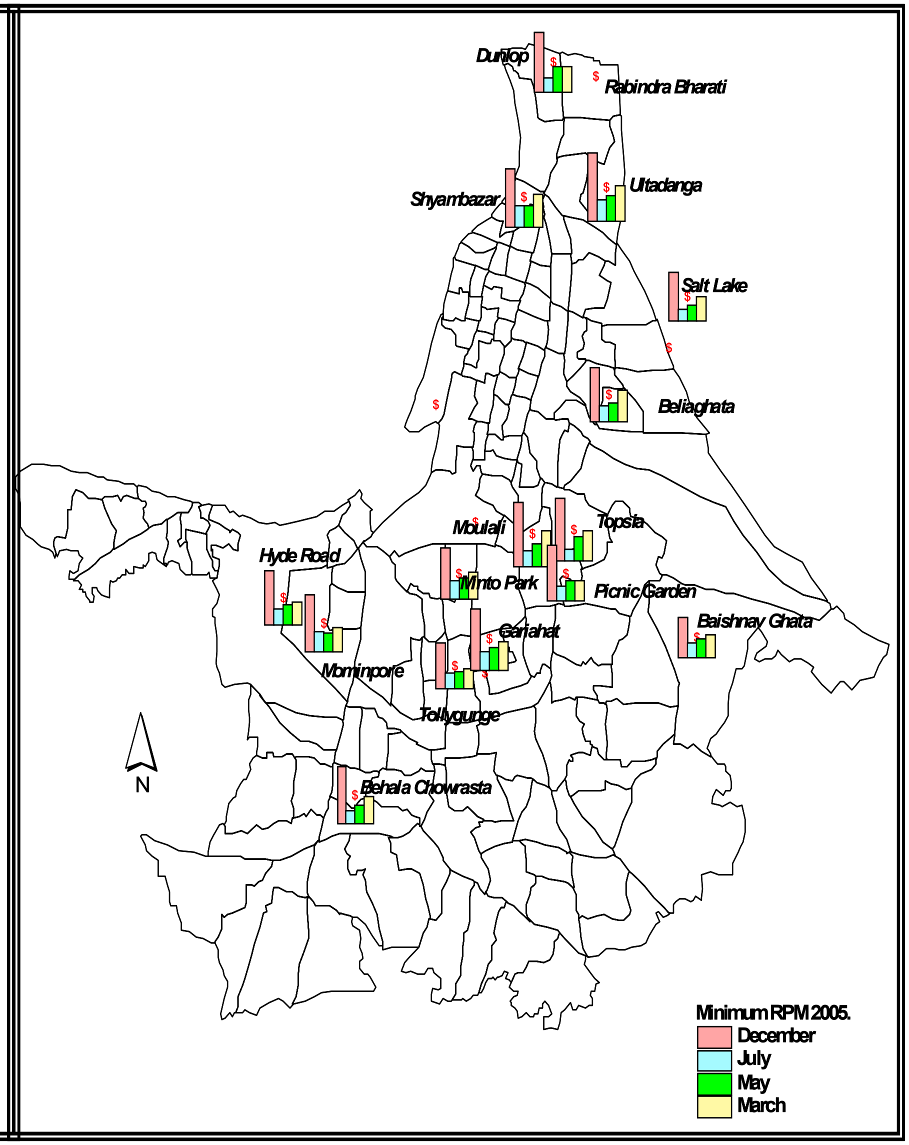

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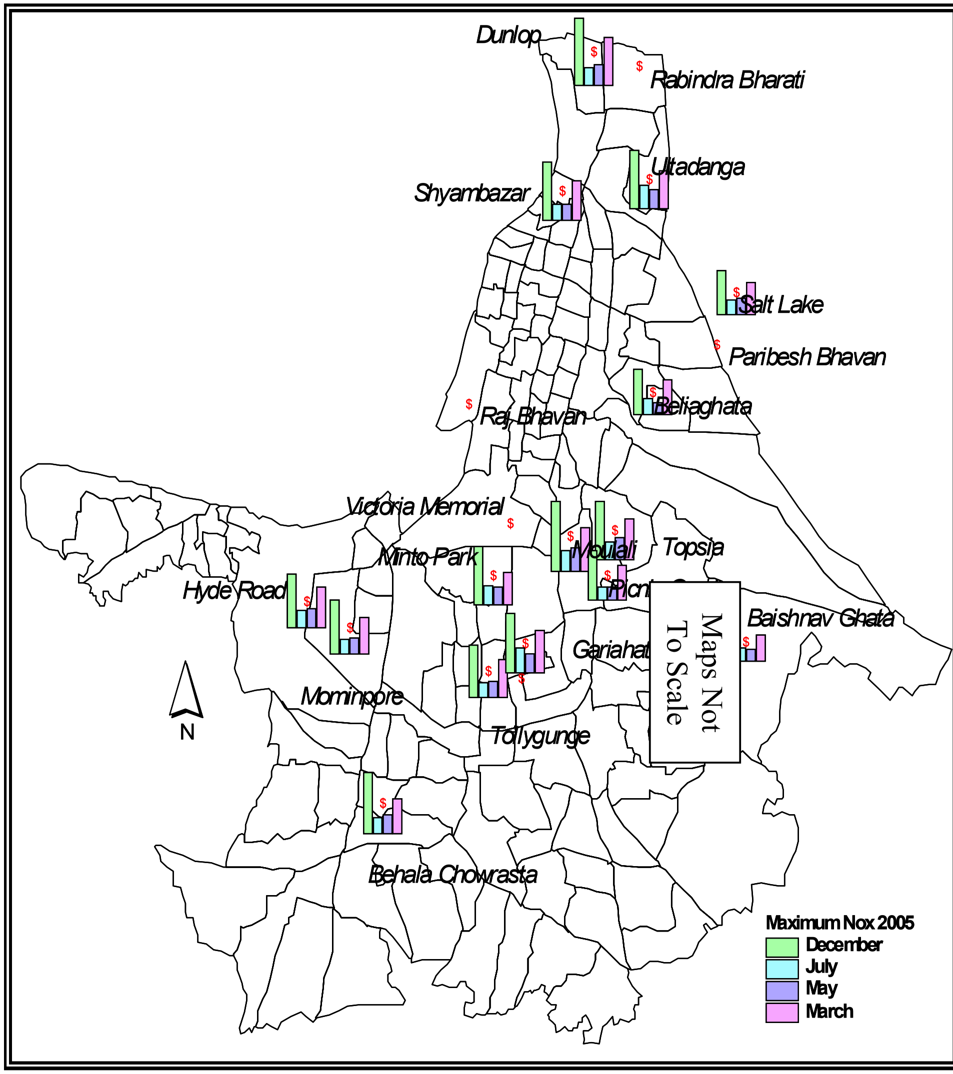
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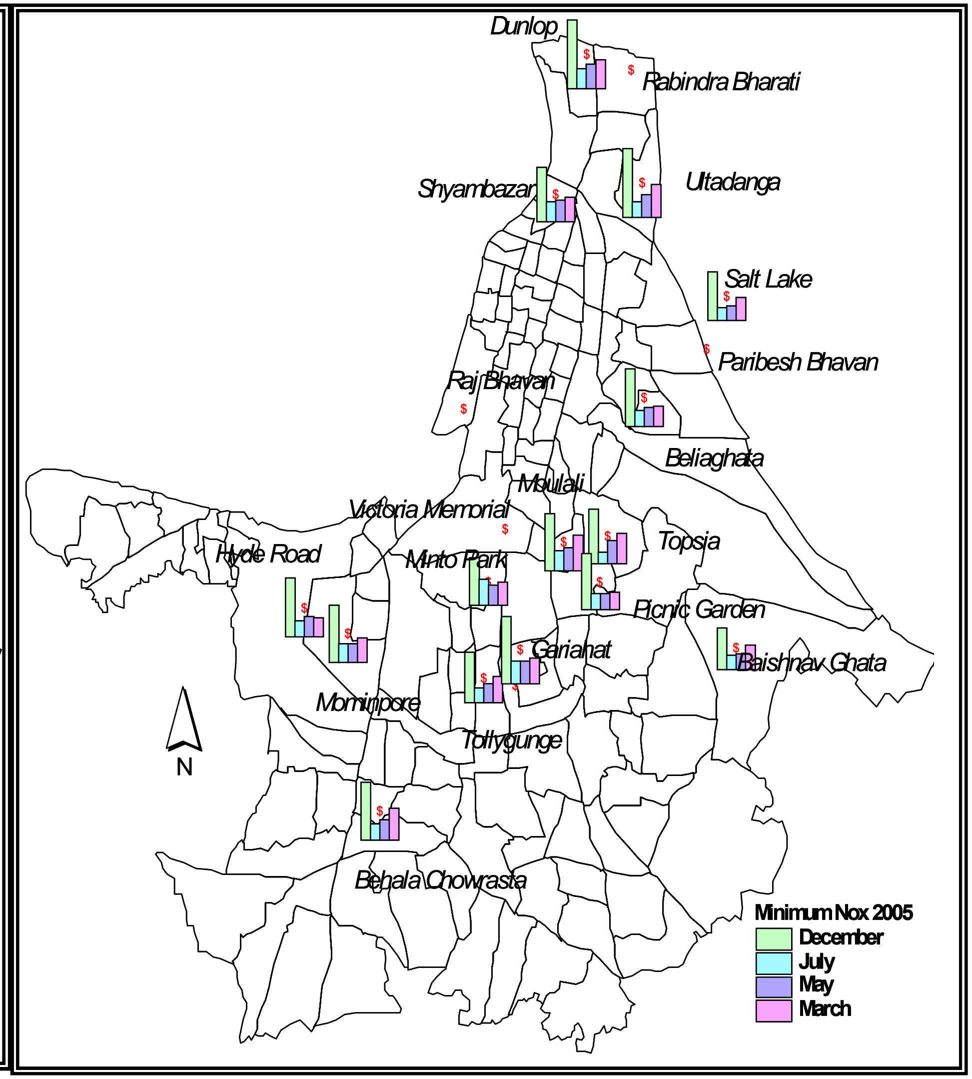
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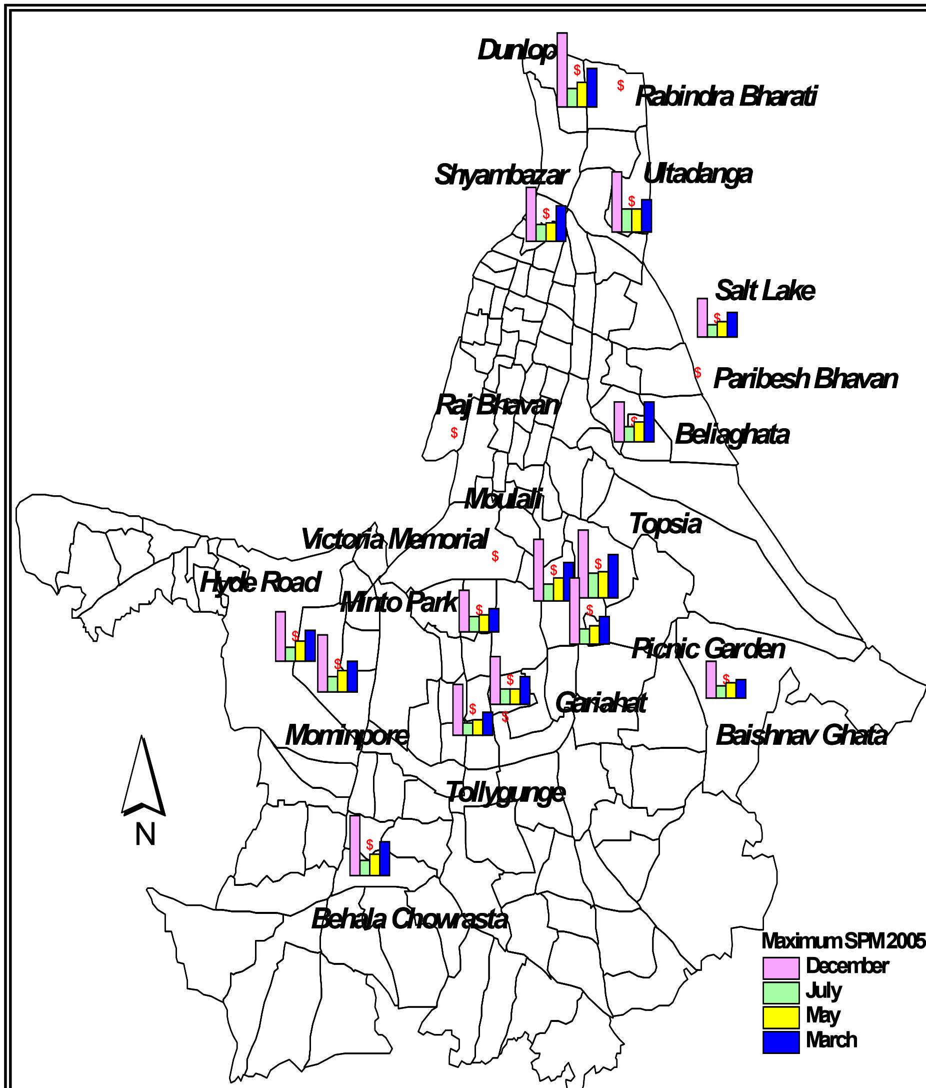
SPM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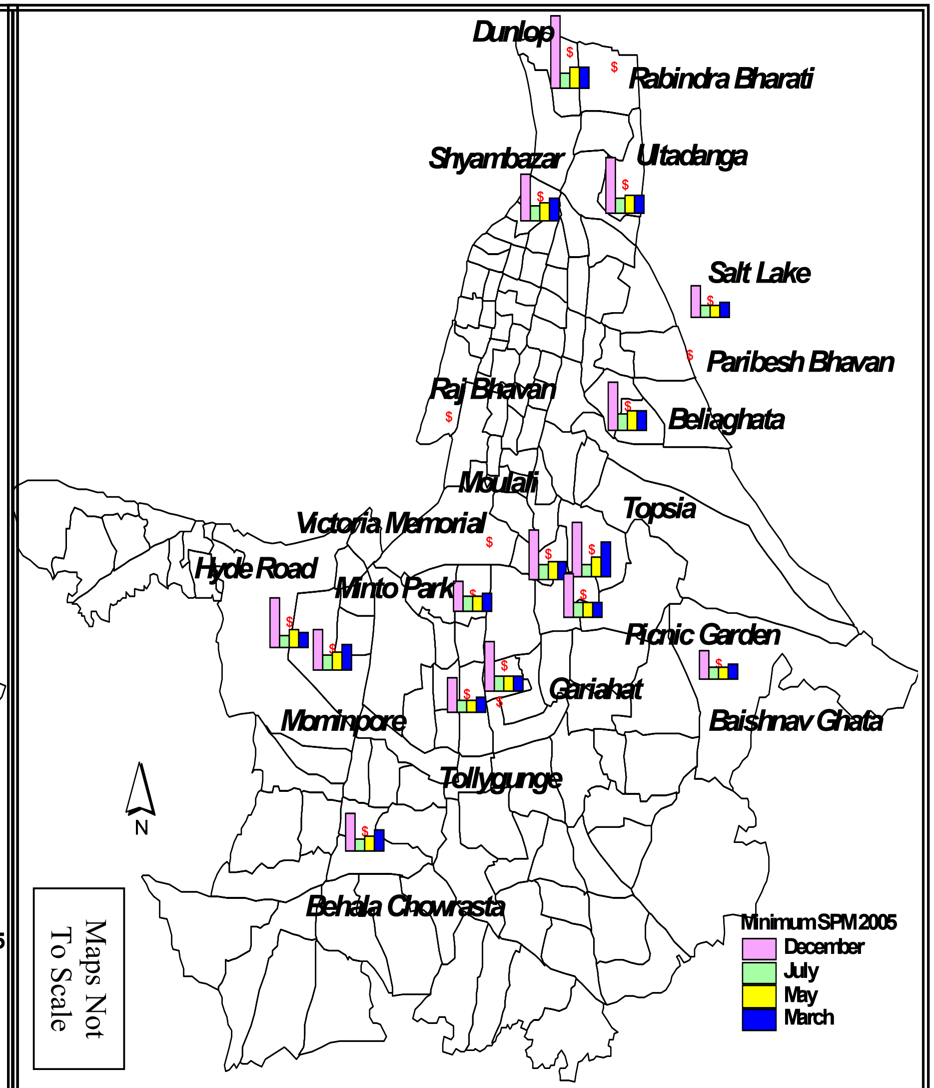
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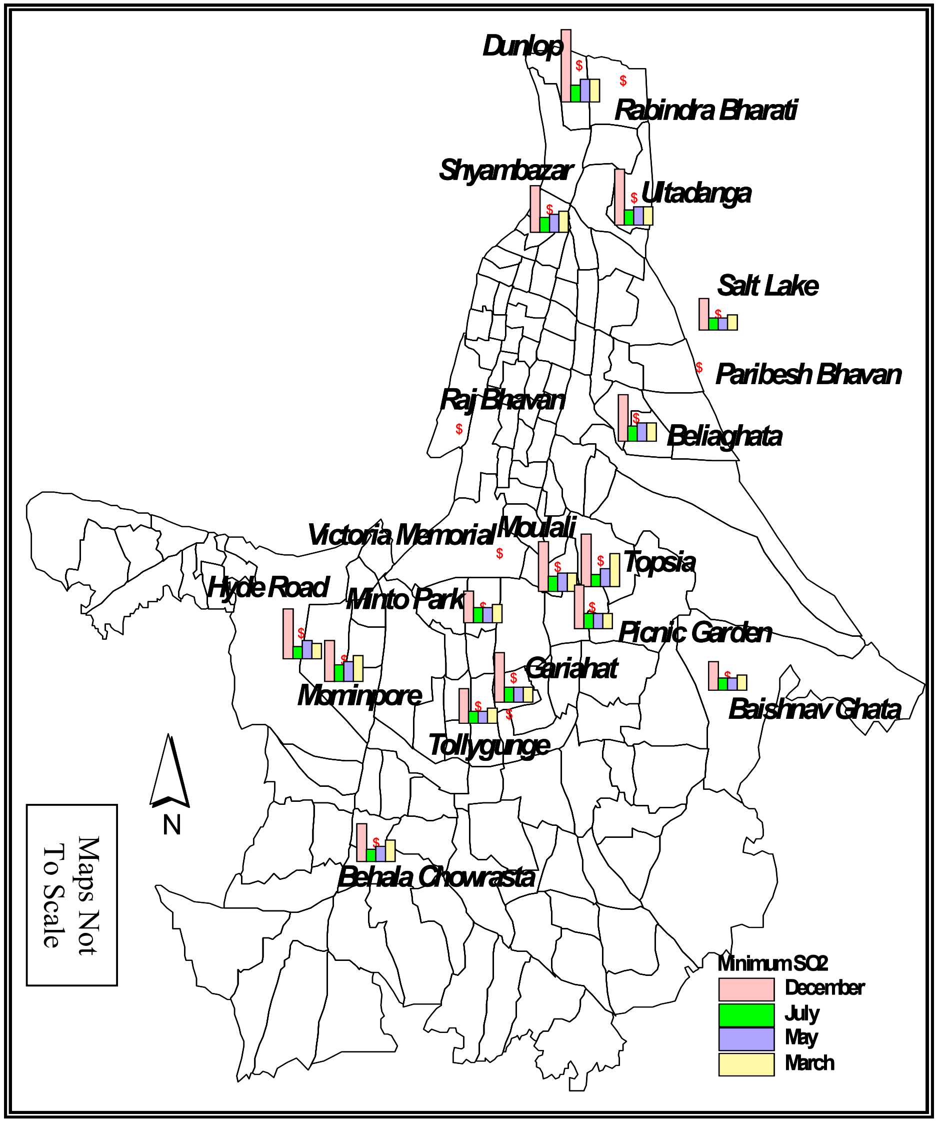
SO2 - 2005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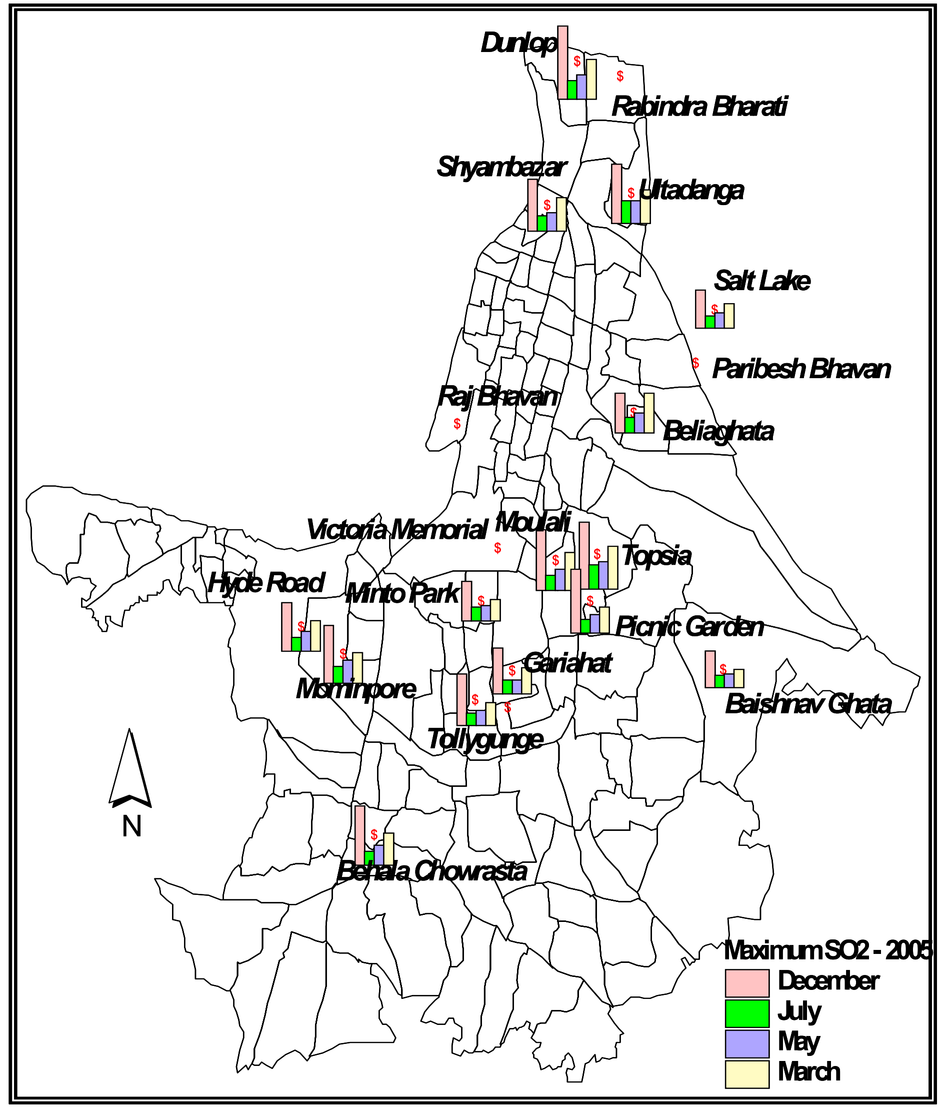
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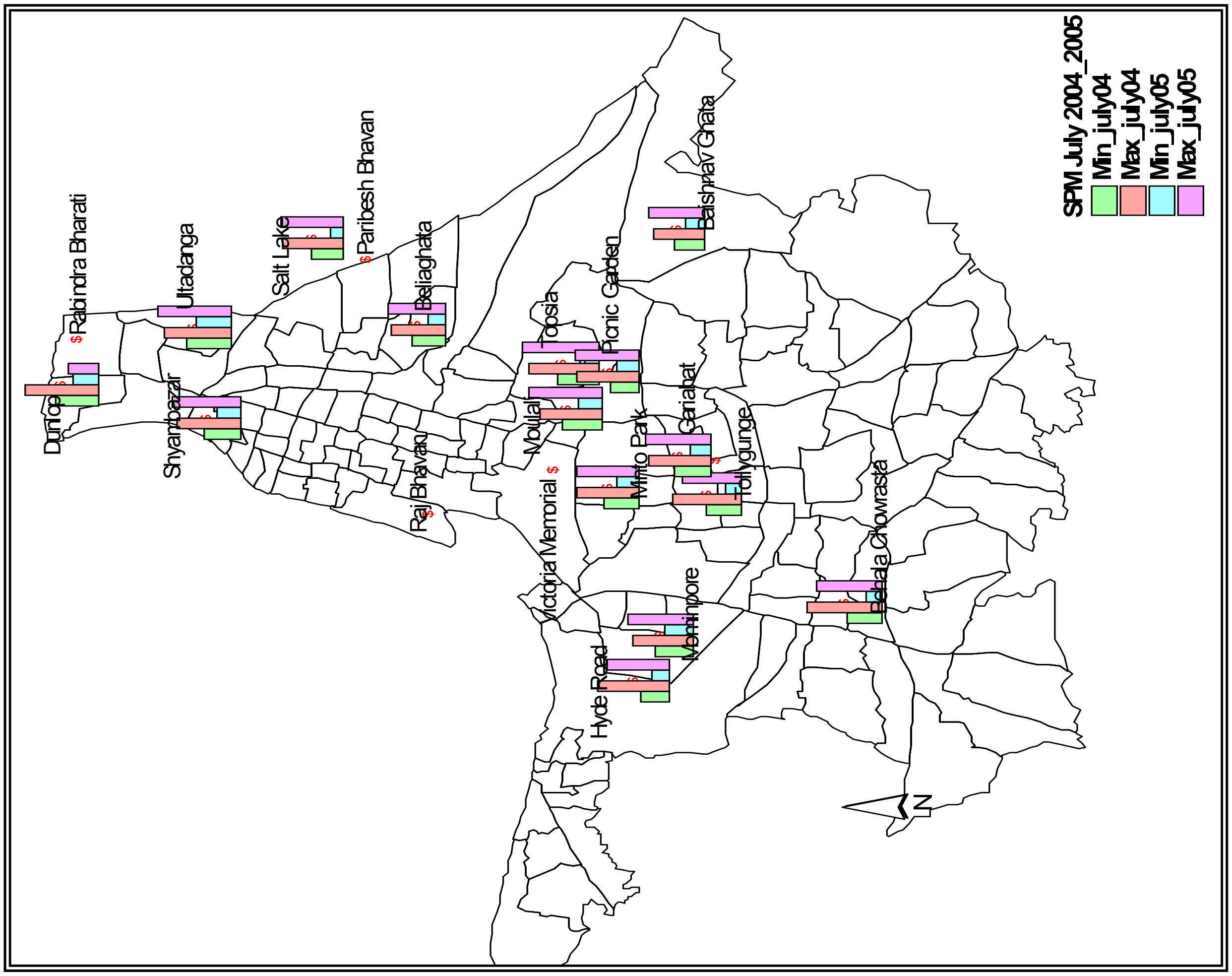
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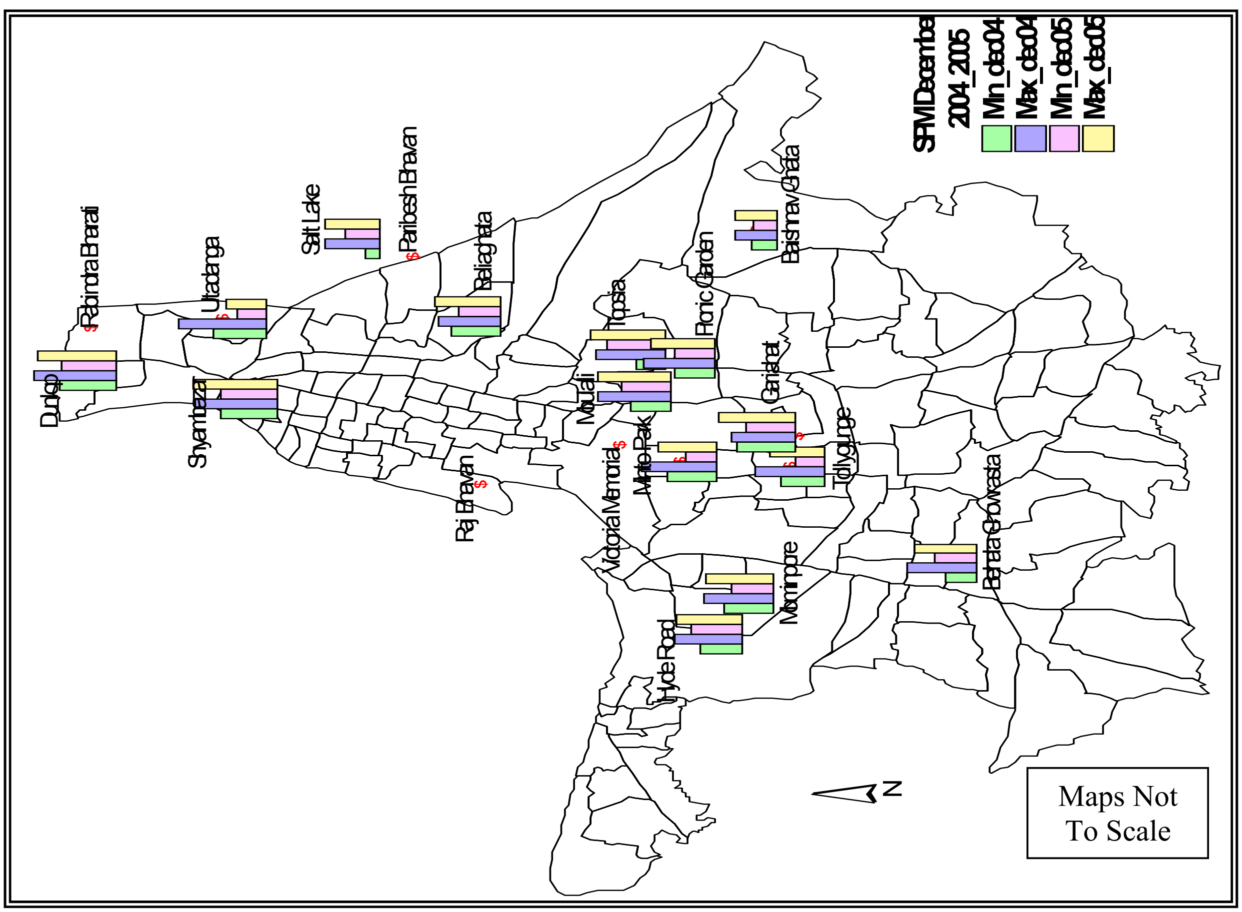
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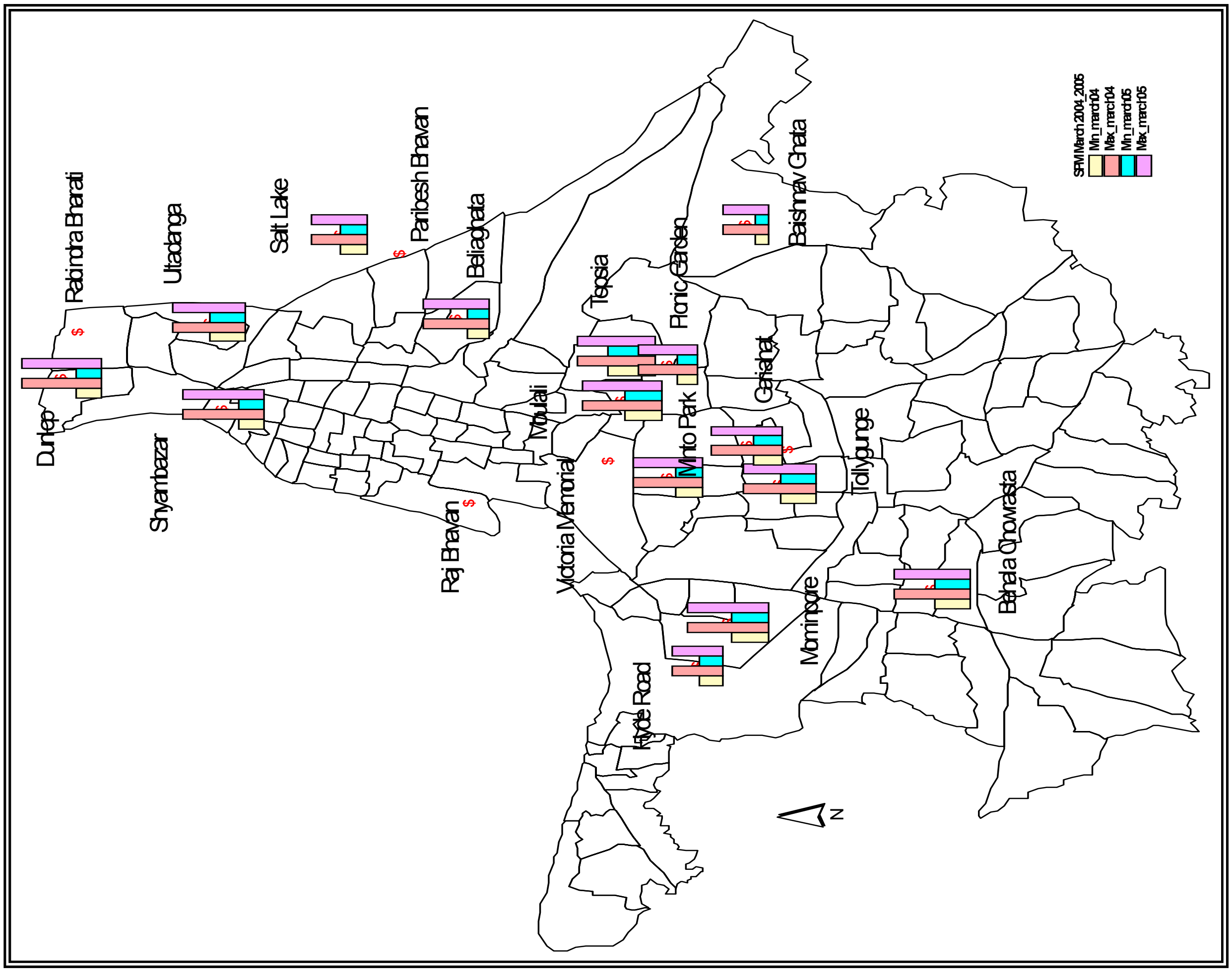
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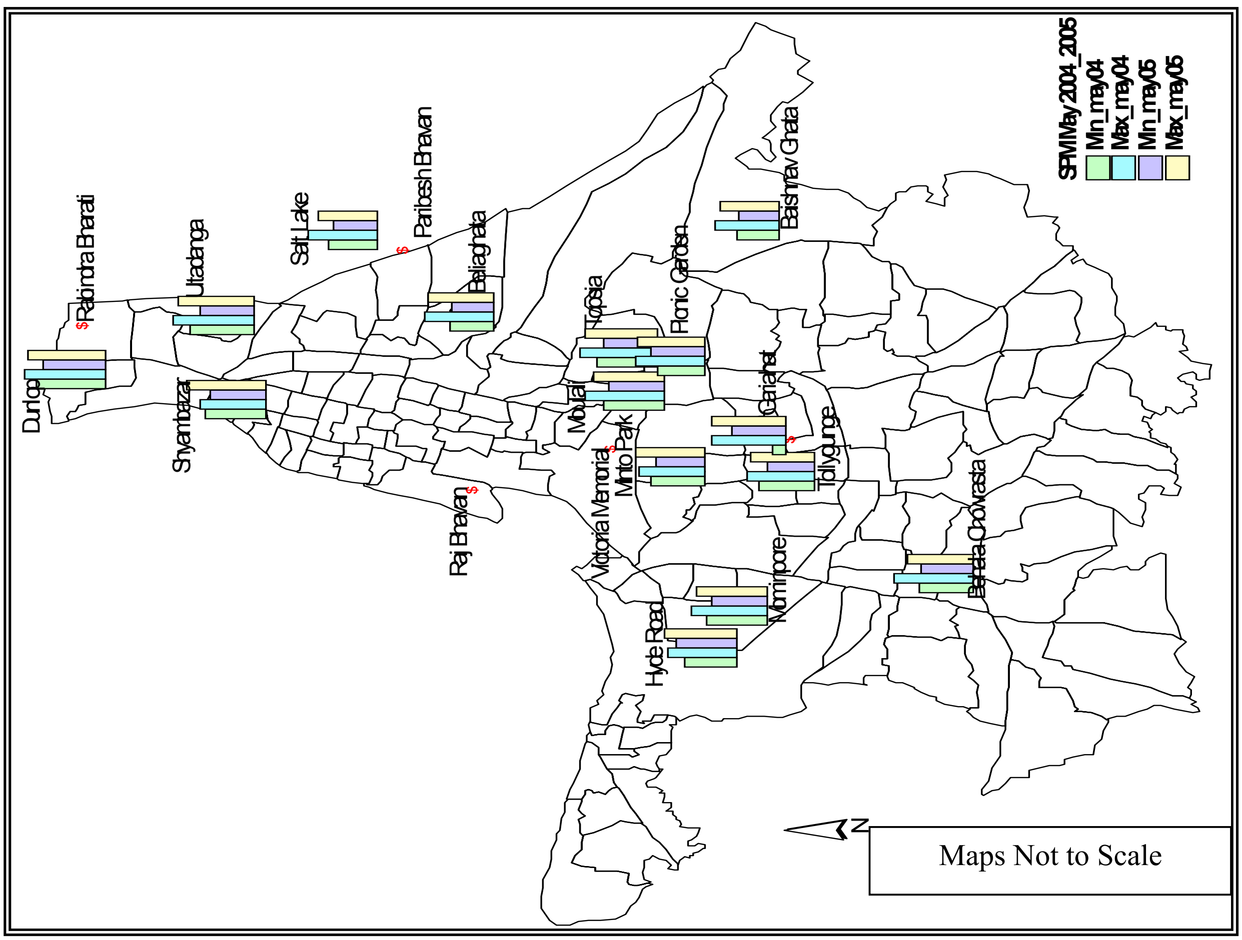
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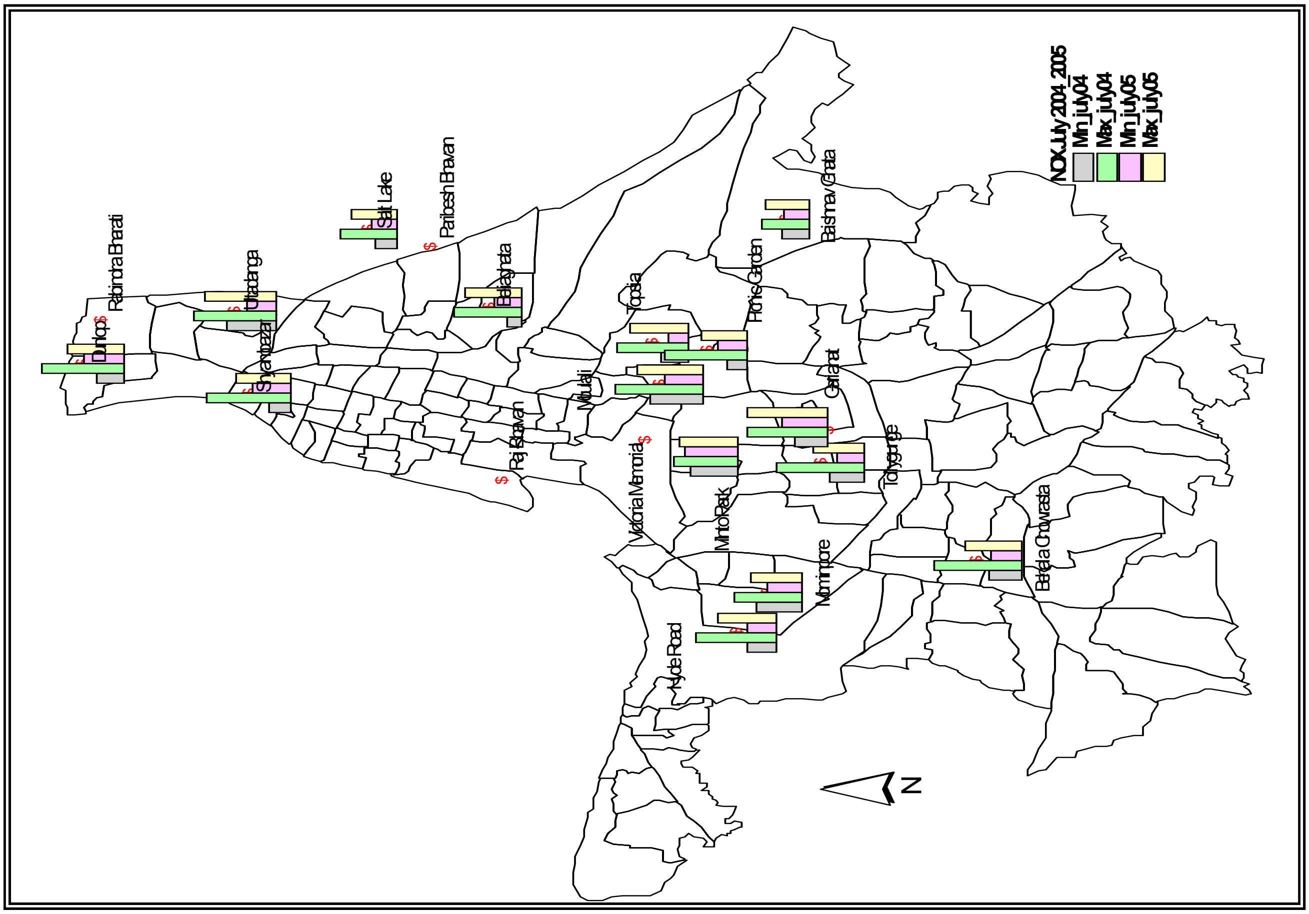
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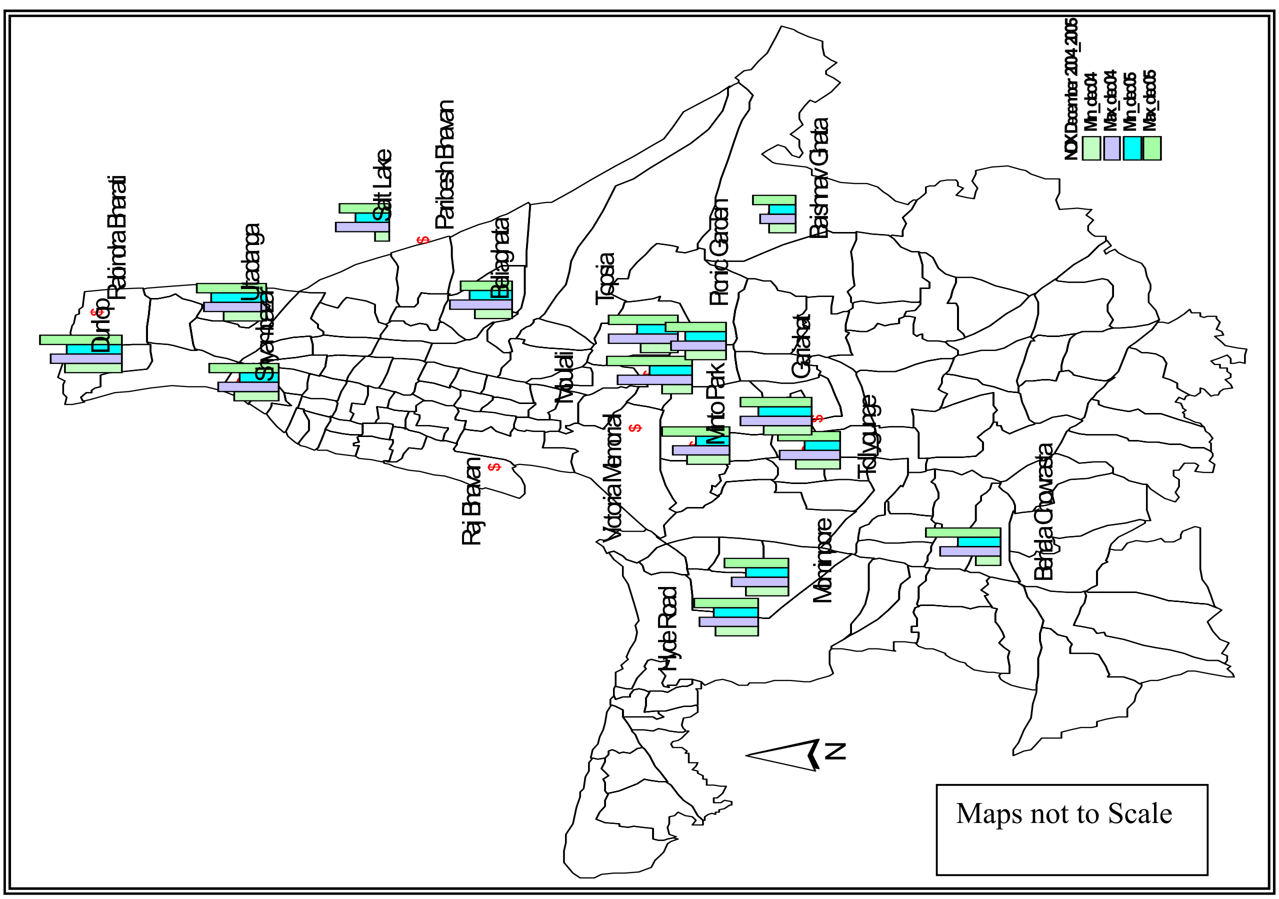
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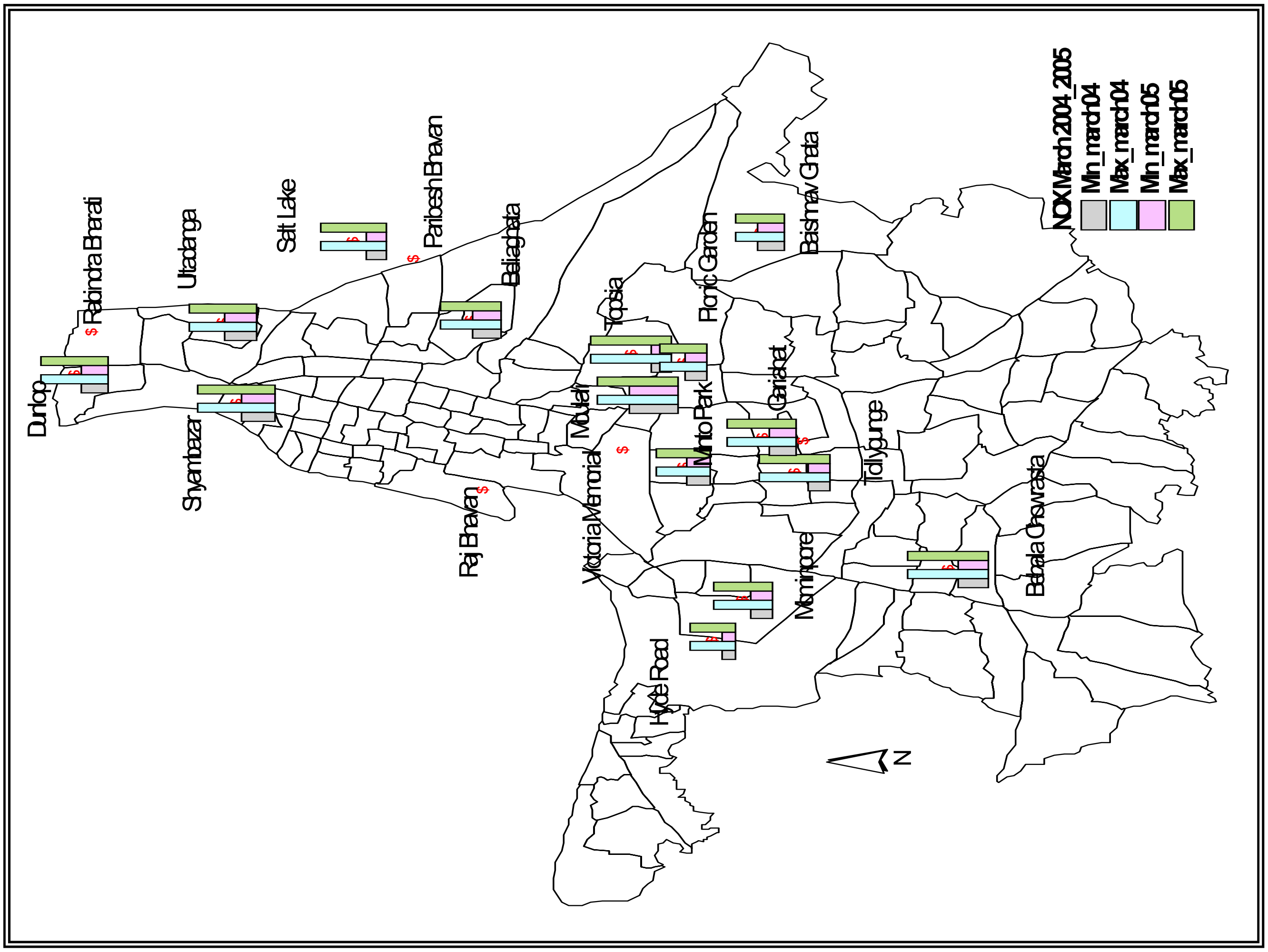
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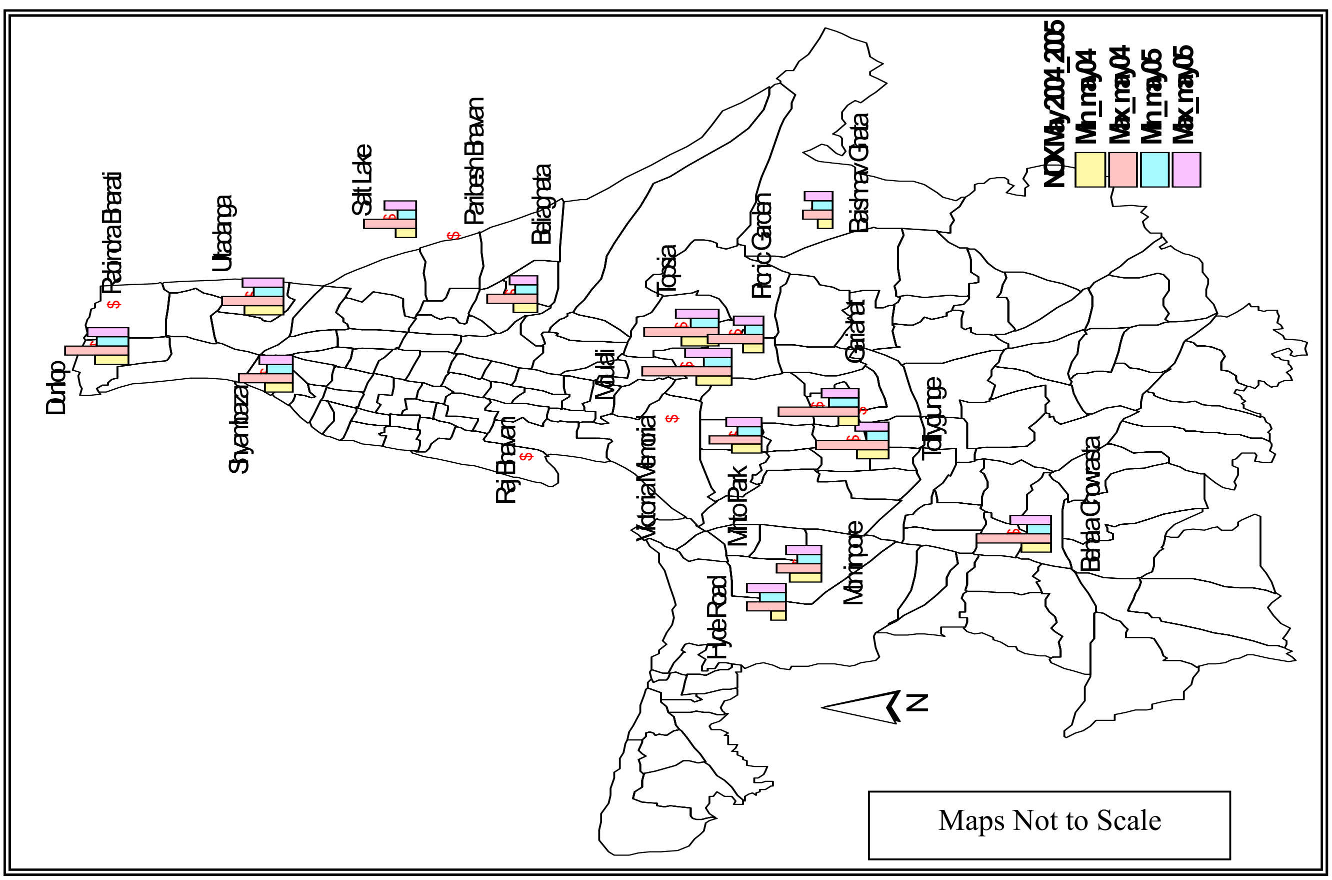
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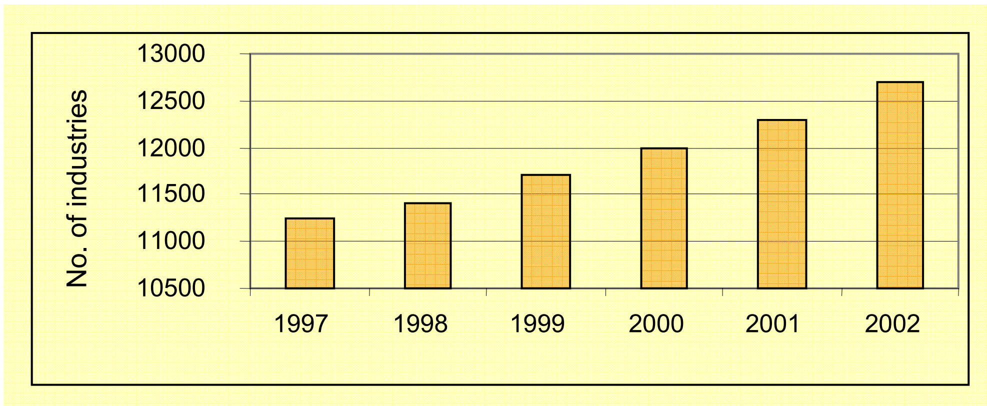
Sectoral apportionment of the flows can be used to prepare supply use table format. In KMC area construction sector is the major point source and transport is the major mobile source.

Fig. 4.1: Number of registered large-scale industries in West Bengal during the years (Source: Labour in West Bengal, 2002 department of labour)



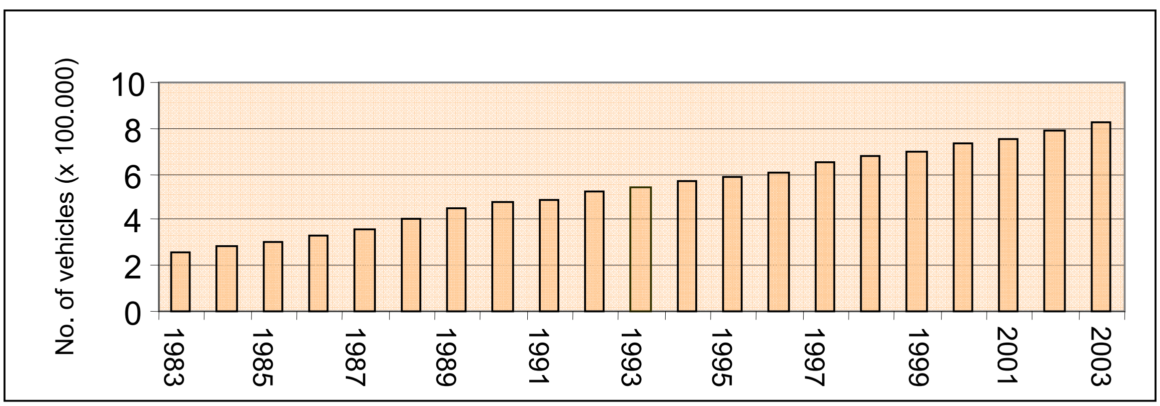


Fig. 4.2: Number of vehicles registered in Kolkata during the years

The high level of air pollution in the air is also due to the high amount of traffic in the streets of Kolkata. The use of old vehicles (especially the pre-1990 vehicles), the lack of road space which is not in proportion with the increasing vehicle fleet (fig. 4.2) and absence of proper inspection and maintenance system is causing the air pollution. Kolkata has 90 auto emission testing centres (AETC's) but only 18% to 30% of the 1.2 million vehicles of Kolkata appear for the tests. At least 70% of all vehicles should have Pollution Under Control (PUC) certificates. PUC certificates are given out if the vehicles are found to emit exhaust gases complying with the statutory emission standards (source: Times of India, 16 March 2006). Every vehicle mechanic is able to submit an application for the set up of an auto emission testing centre at the WBPCB.

In May 2005 the state government of West-Bengal issued a notification stating that no public transport vehicle registered before January 1, 1990, would be allowed to ply in the Kolkata Metropolitan Area (KMA). The state government submitted a study report stating that the pre-1990 vehicles were responsible for rising pollution levels. The study reveals that nearly 60% of all vehicular pollution is due to pre-1990 busses alone. Unfortunately the ban on old vehicles has been recently striked down by the high court. The Bengal Bus Syndicate (organization of private bus owners) stated that the notification was unreasonable. The bus owners submitted that there were inadequate provisions to provide a cleaner fuel (like compressed natural gas) for public transport vehicles.

It was also pointed out that not much has been done by the state government to facilitate the conversion of engines of ageing vehicles. It is however still possible to ban taxis from KMA that are over 15 years old. According to West Bengal motor vehicles rule of 1989 a taxi has a life of 15 years, with an additional grace period of a further two years. Thus the government can still force vehicles older then 17 years to switch over to a cleaner fuel like LPG (source: Times of India, 16 march 2006).

In addition to industries and automobiles, burning of coal in domestic sector also contributes to air pollution. Most of domestic coal burning in urban areas is found in the slum areas. About 3.8 million of the population of West Bengal lives in slums accounting for approximately 17 percent of the urban population in the state. A large part of particulate matter (SPM and RPM) in the air may also come from combustion of biomasses like dry leaves, coal and woods, re-suspension of road dust, construction activities and garbage dumping. The contributions from these sources are however yet to be quantified.

IV. Impact assessment through health damage cost analysis: Methodology Adopted

In the present exercise the cost of illness approach is employed to derive estimates of health benefits in one of the most polluted cities of India, viz. Kolkata.

The main components involved:

- Collection of basic statistical data. Data includes general information about the area of the city, the density of population, sources of pollution, the nature of pollution, the pollution levels etc.
- Designing the questionnaire to carry out household surveys
- Selection of hotspots in the city of Kolkata since the number of pollution monitoring stations was across large area.

Kolkata has a total area of 1036 sq. kms. However, it is the most densely populated city of India (11,680 persons per sq. km in the year 2001). As per the Census of 2001, the urban agglomeration's population was 13.2 million while that of the city (Municipal Corporation of Kolkata) was 4.5 million. About half of the total air pollution load of Kolkata is contributed by automobile exhausts, especially from diesel driven vehicles and the other half comes from the industrial units. The total registered vehicular population in Kolkata has more than doubled between 1990 and 2003 from 5.4 lacs to 12.3 lacs. The RSPM (respiratory suspended particulate matter) levels responsible for respiratory illness have been found to be alarmingly high in Kolkata. The effective road area available in the city is around 6 per cent of the total area. In Howrah (the twin city of Kolkata), the pattern is even worse. Very high and increasing automobile density, disproportionately low percentage of road network, congestion and slow traffic movement, aging of vehicles, registration of discarded vehicles from elsewhere, poor quality of fuel and unscientific traffic management are a few major reasons for highly polluting automobile exhausts. One official survey in Kolkata found that in 1998-99 more than 90 per cent of the industrial units had neither obtained air consent from the West Bengal Pollution Control Board, nor had proper stacks within the premises, thereby creating an environmentally problematic situation for the entire locality. Industrial emissions from around 15,000 industrial units of varying capacities operating now within the metropolitan area are contributing to a substantial pollution load in Kolkata.

V. Designing the Questionnaire

A questionnaire has been designed in two parts to carry out household surveys. Part A has questions seeking information about the socio-economic characteristics of the households. Part B has questions to get data for estimating the household health production model. The answers by the respondent to the questions in Part A of the questionnaire provide data about the respondent's occupation, time spent outdoors in terms of journey hours on road, family size, gender and age composition of the family, the education level of members of the family, the monthly expenditure of the household. The household responses to the questions in Part B provide data on the awareness of households about the effects air pollution on health, the source of their information, opinion of the household regarding the air quality in the city, the health history of household over last six months in terms of any pollution related diseases and the duration of illness, mitigating activities, i.e. household expenditure on diseases mentioned during the recall period, and averting activities (activities to avoid exposure to out door pollution). An alternative measure of the health status of each household is captured by the total number of doctor visits made by each member of the household over the last six months. Number of visits by each family member is added up to arrive at the figure for the respective household. It also includes questions on the habits of the respondent and his family members with respect to smoking, taking alcohol and taking exercise (including morning walk) regularly. Finally it also includes questions on the respondent's opinion whether outdoor pollution has affected his recreation, and the willingness to pay for avoiding an additional day of illness on account of outdoor air pollution on behalf of the respondent's family.

VI. Selection of Hotspots in Kolkata

Kolkata has 17 monitoring stations for air pollution run by the West Bengal Pollution Control Board (WBPCB) while Howrah has 3 monitoring stations run by the Central Pollution Control Board (CPCB). Some detailed block identifying maps (from the Municipal Corporation of Kolkata) for the city of Kolkata, were used to identify the residential blocks to be surveyed under each monitoring station. With reference to the objective of conducting surveys as part of the project to measure welfare gains in terms of health benefits from reduced air pollution, we have tried to select the hotspots of air pollution in Kolkata, since the number of monitoring stations is too many in number.

The criteria for selection have been:-

- Population density/growth rate.
- Day to day concentrations of various pollutants at the different monitoring stations identified by the WBPCB.

For a place which is high both on its population count as well as on its concentration of air pollutants, is definitely the one to be heeded. In such a place we have more people over exposed to pollution. A close scrutiny of the day to day concentrations of NO2 and

SPM in the city atmosphere reveals that their concentrations have been quite high for the major part of the year and they have consistently over shooted their residential standards over the winter months (November, December, January and February).

To begin the process of identification we considered separately the daily ambient concentrations of NO2 and SPM at the 15 monitoring stations, namely DUNLOP BRIDGE, PICNIC GARDEN, TOLLYGUNGE, HYDE ROAD, BELIAGHATA, SHYAMBAZAR, GARIAHAT, BEHALA CHOWRASTA, MOULALI, SALT LAKE, TOPSIA, BAISHNABGHATA, MINTO PARK, ULTADANGA and MOMINPORE, for which data are available from the West Bengal Pollution Control Board (WBPCB). Then for each month we sorted out the 5 most affected stations as measured by their NO2 and SPM concentrations.

Next we formed a frequency table to find the stations, which are most frequent in the monthly lists of 5 most affected stations. The frequency table reveals that these places happen to be the Dunlop Bridge, Behala Chowrasta and Mominpore, Ultadanga and Gariahat. However we have left out Mominpore from the list of hotspots, the reason being that it is partly an industrial and partly a residential area. Our purpose is to study air pollution in residential areas only. On account of population numbers also, Ultadanga, Dunlop Bridge, Behala and Gariahat happen to be either very densely populated or very fast growing. Ward numbers 12 and 13 of Ultadanga, rank respectively 35th and 59th and ward number 131 of Behala ranks 38th among the 141 wards when it comes to their population densities. Though the other wards of Behala are not very high on their population density count, they have very high rates of population growth. For example: Ward numbers 7, 8, 9 and 10 of Behala ranked 18th, 19th, 23rd and 25th when it comes to their growth rates. As for the region around Dunlop Bridge, ward numbers 17, 18 and 19 rank 29th, 14th and 26th respectively when the wards are arranged in order of their population densities. Similarly the other wards around the Dunlop Bridge are either very 19 densely populated or are growing quite fast. Gariahat does not trail far behind with such wards like the ward nos. 85 and 86 making them the 43rd and 56th places on account of their population densities. Moreover the NO2 concentration at Gariahat remains high almost all the year round. This makes Gariahat a major place of concern. Hence the four identified hotspots happen to be BEHALA CHOWRASTA, ULTADANGA, DUNLOP BRIDGE and GARIAHAT.

VII. Conducting surveys

The survey was conducted in the months of November and December 2005 and January 2006. Residential areas within 5 km radius of the air pollution monitoring station by in the four hotspots chosen were surveyed. Respondents were divided into three income groups. They were the high income group (monthly income greater than Rs.15000), middle income group (monthly income between Rs 8000-15000) and low income group (monthly income between Rs 3000 and Rs.8000).

Table 2 Households surveyed according to income groups in Kolkata

Income Groups	Income Classification(Rs./month)	Kolkata
Low income	3000-8000	130 (51%)
Middle income	8000-15000	80 (31%)
High income	15000 and above	46 (18%)

Note: Figures within parenthesis denote the % of households
Source: Obtained from the surveys

VIII. Major survey findings

On the basis of the surveys conducted in Kolkata , the respondent's perception about the diseases which they attribute to air pollution is shown in Table 3. For this purpose a near exhaustive list of 17 ailments have been prepared which was put forward before the respondents for comments.

Out of the 256 respondents interviewed in Kolkata, 95% of the respondents in Kolkata believe that asthma attacks may be attributed to air pollution in the atmosphere. It is obvious that the perception about diseases are based on the respondents past experience about the disease. Either the respondents or his family members have suffered from it, or the respondents know other people who suffer from the disease. Following this modal class is the second largest class of observation, which contains 227 observations, which is about 89 per cent of the respondents. These are individuals who attribute the incidence of headache to pollution. About 85% of the respondents have indicated that eye/nose/throat irritation, as well as allergy to dust are consequences of air pollution. This 20 was followed by 83% and 76% of the respondents who attributed skin infection and heart diseases respectively to the air pollution problem.

Table 3 Perception about diseases in the city of Kolkata

Perception of Diseases	Kolkata	
	Frequency	% of respondents
Headache	227	88.6
Eyes/nose throat irritation	219	85.5
Runny nose/cold	171	66.8
Influenza and/or fever	51	19.9
Skin infections and rashes	213	83.2
Asthma attacks	244	95.3
Shortness of breath	176	68.7
Respiratory allergy to dust	219	85.5
Dry scratchy throat	103	40.2
Chest pain	122	47.6
Cough and phlegm	64	25.0
Dry cough	153	59.7
Bronchitis	76	29.7
Drowsiness	69	26.9
Pneumonia	31	12.1
Disease of the heart	196	76.5
Cancer	67	26.2

In Kolkata, a maximum of 244 respondents claimed that one of the chief effects of air pollution was an increase in the incidence of asthma attacks making this class the modal class with 95.3 % of the observations. A total of 227 respondents (88.6%) pinned down air pollution as the main cause behind increasing headaches. The next class, with 219 responses, comprising of nearly (85.5%) of the total observations maintained that along with eyes and nasal irritations, respiratory allergy to dust were one of the chief fallouts of air pollution. This was followed by people complaining about cold and skin infection etc. Also it can be seen that the people in Kolkata experience serious diseases like heart ailments, cancer and bronchitis.

One of the most important pieces of information collected during the survey was the respondents' views regarding the status of air quality in the city over the last few years.

Provision was made to accommodate all kinds of responses. The nature of responses can be seen from Table 4. Out of the 256 households interviewed in Kolkata, almost 44% replied that the air quality has been deteriorating and 21% replied that air quality has not changed.

Table 4 Perception about Air Quality

	Kolkata	
Perception about Air Quality	Frequency	Percentage of Values
Improved Initially then Deteriorated	42	16.4
Deteriorated Initially then Improved	29	11.3
Has Not Changed	54	21.1
Has Been Deteriorating	112	43.7
Has Been Improving	19	7.4

Efforts have been made to find out what the people of the chosen areas think about the status of air pollution in their city. The survey reveals that 89% of the respondents in Kolkata feel that the condition of pollution to be very serious in the city with another 8.5% who think that the pollution problem is moderately serious. Various steps to combat the air pollution problem have been taken. No new Red category industries are permitted to set up within the municipal areas of the Kolkata metropolitan area (KMA). About 24 industries in Kolkata and 66 in Howrah, with high air pollution potential, have been identified. These industries are inspected and monitored regularly on a fixed schedule. Non-compliant industries are dealt with by imposing heavy bank guarantees, forfeiture of bank guarantee, temporary closure and in some cases relocation. The WBPCB has also introduced stricter emission standards for boilers, ceramic kilns, foundries and rolling mills operating within KMA. To change coal fired heating equipment to oil/gas fired ones in units using small boilers and ceramic kilns within the KMA, financial assistance is being provided by the WBPCB and India Canada Environment Facility. Industries are encouraged to go ‘beyond compliance’ and good performers are honoured with ‘Environmental Excellence Award’. Low sulphur petrol and diesel (containing 0.05% sulphur) are made available within Kolkata and Howrah and adjoining urban agglomeration from 01.01.2001.

In view of this background we wanted to know what the residents of Kolkata felt about the impact of these and other recent developments on the air quality of their cities. Attempts were made to determine as to which of the following activities have had a positive/beneficial, negative/harmful, or neutral/neither harmful nor beneficial impact on air quality of the city. Keeping in perspective the fact that awareness levels vary from individual to individual as well as over localities, the following responses were obtained from the city (Table 5).

Table 5. Impact of different activities on air pollution -Responses from the two cities

Impact on air quality	% of positive response	% of negative response	% of neutral response	% of ignorant response
Construction of new roads and flyovers				
Kolkata	39.8	22.6	21.8	15.6
Use of cleaner transport fuels				
Kolkata	45.7	9.7	17.6	22.9
Newer vehicles on the road				
Kolkata	62.8	12.1	7.8	17.2
Closure of air polluting industries				
Kolkata	49.0	13.3	9.4	28.3
Cleaner fuel use in industry				
Kolkata	48.2	8.6	8.9	34.3
Compliance of industry with regulation				
Kolkata	30.6	12.8	11.7	44.9
Maintenance of urban infrastructure				
Kolkata	28.0	33.8	12.5	25.7
Ban on open burning of garbage				
Kolkata	39.6	23.8	6.6	30.0

In Kolkata, about 63% of the respondents believe that newer vehicles on road have improved the air quality. Responses of such a nature may be attributed to the fact that the households are aware that nation-wide automobile manufactures are introducing new models into the market which have improved fuel efficiency and which adhere to emission norms and hence emit less smoke. 12% individuals however opined that newer vehicles will further worsen the situation. Survey analysis also reveals that 49% of the respondents feel that closure of air polluting industries is going to have a beneficial effect on the air quality. On the other hand in Kolkata, people feel that newer vehicles on road will improve the situation. In Kolkata people feel that since most of the vehicles on road are very old and use adulterated petrol, therefore newer vehicles will probably improve the air quality.

As regards the nature of pollution averting behaviour of the individuals, information regarding three kinds of averting behaviour was recorded. They were staying indoors, using masks on roads and avoid busy roads and timings. In Kolkata merely 61% of the respondents undertook some kind of averting activity, with the maximum going for avoiding busy roads (32%). In Kolkata 78% of the respondents said that their recreation was affected.

IX. Data and model formulation

The following endogenous and exogenous variables are formulated for the model.

- **Endogenous variables**

Health status of the Household (Y1): The number of days of sickness in each household over a period of 6 months is used as a measure of the health status. This information was obtained by directly asking the respondent about the total days of sickness for each adult and child member in that household over the last six months that they have experienced. The number of days was then added up for each person to arrive at the total number of sick days for the household.

Doctor Visits (Y4): An alternative measure of the health status of each household is captured by the total number of doctor visits made by each member of the household over a period of 6 months. Number of visits by each member is added up to arrive at the figure for the household. This information is collected from the respondent.

***Mitigating Activity (Y2)*:** The total medical expenses of the household (including doctor fees, medicines and diagnostic tests) in the last 6 months, was used to denote the total expenses on mitigating activities. The reported figure for each household is a cumulative one including expenses for all the adult and child members.

Averting Activities (Y3): An ordered variable in the range of 0 to 4 is used to measure the averting activity for each household, These activities includes number of days stayed indoor to avoid exposure to pollution, extra miles traveled in a day to avoid polluted areas in the city, using a gas mask while traveling and any other household specific averting activities. Undertaking all activity scored 4 and the absence of all was marked at 0. This was also based on the input from the respondent.

- **Exogenous variables**

Air Pollution Exposure Index: The exposure index of the household is constructed for SPM and NO2 separately. Assuming different hours of exposure, to local air pollution for household members belonging to different age groups (18 hours for children, 15 hours for 26 adult females and 12 hours for the adult male members, 16 hours for college going students etc) and also adjusting for their time spent in traveling, a weighted index of exposure was constructed thereby converting the area specific information on pollution concentration into a household specific one.

Exposure to SPM = (‡”iTi)/24 x SPMj

Exposure to NO2 = (‡”iTi)/24 x NO2j

Where Ti is the time spent by member i of the household in his/her locality after adjusting for the office/work/school hours and time spent in traveling to the workplace. Hence ‡”iTi denotes the total time of all the members of the household in any particular locality j. SPMj and NO2j are the average concentrations of SPM and NO2 in locality j over the months of November-December 2004 and January 2005 (only the weekdays, Monday to Friday have been considered while computing the averages). The exposure indices for SPM and NO2 are respectively termed as X1 and X2.

Chronic Disease Index (X3): The index for chronic diseases which measures the health history of the household, is an ordered variable of the range 0 to 8. Out of the 8 chronic diseases considered viz. Diabetes, High BP, Glaucoma, T.B., Cancer, Asthma, Heart disease or anything specific, a household that has none of these scores 0 and the one with all is pegged at 8.

Family Size (X4): Family size operates as a control variable for higher days of sickness or medical expenses in a large sized household. Information is collected from the respondent.

Habit Index (X5): The number of bad habits that infested the family of each respondent was recorded in the questionnaire and was subsequently committed to form its respective habit index. The index for habits is constructed by considering the presence of bad habits like smoking, drinking, not going for morning or evening walks and not exercising in the household. Information on this is collected from the respondent. It functions as a control variable in the estimation of household health production.

Awareness for air pollution borne diseases (X6)**:** The awareness index for air borne diseases is constructed by taking the proportion of the diseases known to the respondent in the total of 17 diseases that are clinically proven to be related to air pollution.

Gross Annual Household Income (X7): The income variable directly reveals the capacity to spend and the actual health expenses among the households. It is based on the gross annual family income of the household. In absence of any concrete figures for actual incomes (which most of the respondents did not want to reveal) it was necessary to obtain at least their monthly expenditures, from which the annual incomes have been estimated approximately. Given a 20% savings rate in the country, total annual income was estimated from the figures obtained on monthly expenditures.

The model used in the estimation is specified as follows:

$$Y1i = \alpha 1 + \beta 1\ X1i + \beta 2\ X2i + \beta 3\ X3i + \beta 4\ X4i + \beta 5\ X5i + \beta 6\ Y3i + u1i \quad (1)$$

$$Y2i = \alpha 2 + \beta 7\ X1i + \beta 8\ X2i + \beta 9\ X3i + \beta 10\ X6i + \beta 11\ X7i + \beta 12\ Y1i + \beta 13\ Y3i + u2i \quad (2)$$

$$Y3i = \alpha 3 + \beta 14\ X1i + \beta 15\ X2i + \beta 16\ X3i + \beta 17\ X6i + \beta 18\ X7i + \beta 19\ Y1i + \beta 20\ Y2i + u3i \quad (3)$$

The above three equations (1) to (3) constitute a simultaneous equation system with three endogenous variables and seven exogenous variables. Equation (1) represents the household health production function expressing the health status given in terms of number of sick days in a household as a function of averting expenditures, exposure to pollution (both SPM and NO_2), and the health stock represented by the variables such as chronic diseases index, index of bad habits and the family size. Equations (2) and (3) represent household demand functions for mitigating/medical expenditure and averting activities. Variables common to both the demand functions are exposure to pollution, disease index, household annual income, index of awareness for air pollution related diseases and the number of sick days. A simultaneous structural system is used to obviate the problem of simultaneity between Y1, Y2 and Y3. The parametric estimations procedure of 3SLS (three stage least squares) has been employed for eliciting the estimates.

X. Results

Out of the total observations 21 for Kolkata had to be excluded as outliers. Parametric estimates of the structural equations, (1), (2) and (3) using 3SLS estimation procedure for the survey data are provided in table 9.

As far as medical expenditure is concerned, results from equation 2 show that all the exogenous variables are showing expected signs. Medical expenditure will go up with an increase in the SPM and NO2 exposures, diseases, annual income and sick-days. On the other hand medical expenses will come down with an increase in the awareness level and increase in the number of averting activities. However, out of the seven explanatory variables, exposure to SPM, diseases and the number of sick-days have a significant impact on medical expenses. On the other hand for Kolkata it is found that increase in the averting activity or awareness level does not lead to a fall in the medical expenses of the households.

Given the estimates the household marginal willingness to pay (MWP) for reduction of one microgram of SPM and NO2 could be estimated

MWPK(spm) = 0.087 + 0.764 + 0.003 = 0.854

Similarly, the marginal willingness to pay for a unit reduction in the NO2 level for Kolkata

MWPK(no2) = 0.076 + 0.145 + 0.006 = 0.227

Table 6 A few descriptive statistics for the city Kolkata

	Number of sick days	Family size	Medical expenses	Number of doctor visit	Lost days due to sickness	No of diseases	Annual income	SPM exposure	NO2 exposure
Mean	12.85	3.89	1844.21	2.17	6.53	1.21	110278.97	1074.32	311.01
Standard Deviation	10.90	1.77	4049.84	1.39	6.36	0.95	62269.64	421.73	126.07
No. of observation	235	235	235	235	235	235	235	235	235

Table 6 provides the mean and standard deviation of the number of sick days in the family, medical expenses, number of doctor visits, family size, lost working days due to sickness, number of diseases, annual income and the family exposure to SPM and NO2 for the recall period of six months. While the medical expenses are already measured in monetary terms, the monetary values of sick days and averting activity have to be estimated. The following methodology is used to estimate the monetary values of sick-days and averting activities. We first calculate the average per day, per capita income earned in each city and also for the pooled observations. Using information from the data of population census in India, it is assumed that 70 percent of urban household members are working members. Thus if we multiply the average per day per capita income by 0.7, we get the per day per capita income adjusted for the number of working members. Using this information, and the value of the coefficient of â1, we can have a monetary estimate of the number of sick-days owing to an increase in the SPM exposure adjusted for a year. On similar lines we can also estimate the monetary estimate of the number of sick-days owing to an increase in the NO2 exposure using the value of â2.

In the household survey, information on averting activities is collected by asking about whether any members of the family are involved in staying indoors to avoid exposure to pollution, avoid traveling through polluted areas, use masks while going out or any other activity. Thus, averting activity is measured as an ordered variable taking the value in the range of 0 to 4 days stayed indoors during the recall period of six months and an estimate of per day income earned by the adult working member of the family. This income loss is then added with the additional money that one spends due to extra kilometres travelled every day.

The additional money spent due to extra kms travel is calculated given the average estimate of extra kilometers traveled and the cost of one passenger kilometer travel (fuel cost). Since we do not have information on the number of days that a household is staying indoors during the recall period of six months, therefore we use the information on number of workdays lost for a household as a proxy variable along with the estimates on per day per capita income adjusted for the number of working members. The set of tables given as Table 7 provides the details of calculations of the annualized gains for reduction of SPM and NO2. The annualized monetary gains for a representative household as well as the entire urban population for an unit reduction in the SPM and NO2 levels can be seen from Table 7. Table 7 provides the estimates of annual marginal benefits for a representative household as well as the entire population.

Table 7

Table 7.1 Annualized Monetary Gains for a Typical Household due to 1 Unit Reduction in NO2 (Rs)

Location	Sick Days	Medical Expenditure	Averting Expenditure^	Total
Kolkata	9.73	0.29	10.03	20.05

Table 7.2 Annualized monetary gains for a typical household due to 1 unit reduction in SPM (Rs)

Sick days	Medical expenditure	Averting expenditure^	Total
11.14	1.53	5.01	17.68

Table 7.3 Annualized Monetary Gains for the Entire Urban Population due to 1 Unit Reduction in SPM (Rs. million)

Location	Monetary Gains (Rs. million)
Kolkata	80.9

Table 7.4 Annualized Monetary Gains for the Entire Urban Population due to 1 Unit Reduction in NO2 (Rs. million)

Location	Monetary Gains (Rs. million)
Kolkata	91.84

Location	Average per capita per day income	Extra kms traveled per day	Urban Households #	Average number of days a households stays indoor during last 6 months*
Kolkata	91.43	0.5	3057452	6.5

Note:
^ Including Petrol Cost at Rs 3.6 per km.
# denotes the household figures for the city as per Census Data
* Denotes the average days lost due to sickness used as a proxy for number of days indoor.

Table 7.5 Annualized monetary gains from pollution reduction

	Annualized Monetary Gains for a Typical Household due to 1 Unit Reduction in SPM (Rs)	Annualized Monetary Gains for a Typical Household due to 1 Unit Reduction in NO2 (Rs)
Kolkata	17.68	20.05

	Annualized Monetary Gains for the Entire Urban Population due to 1 Unit Reduction in SPM (Rs. million)	Annualized Monetary Gains for the Entire Urban Population due to 1 Unit Reduction in NO2 (Rs. million)
Kolkata	54.05	61.30

Table 7.6 Estimates of the Health Production Function Model Using 3SLS

Location	**Kolkata**
Equation 1: Dependent Variable Y1 (Sick Days)	
Explanatory Variables	**Coefficients (t-statistics)**
X1 (SPM exposure)	0.087 (2.499)*
X2 (NO2 Exposure)	0.076(2.526)*
X3 (Diseases)	4.204(2.508)*
X4 (Family Size)	-0.246(-0.371)
X5 (Bad Habits)	1.778(0.450)
Y3 (Averting	-28.983(-2.146)*

Activity)	
Constant	17.680(1.102)
Equation 2: Dependent Variable Y2 (Medical Expenditure)	
X1 (SPM exposure)	0.764(3.649)*
X2 (NO2 Exposure)	0.145(2.155)*
X3 (Diseases)	301.725(2.342)*
X5 (Awareness)	38.228(0.101)
X6 (Annual Income)	0.002(0.039)
Y1 (Sick Days)	80.5(2.273)*
Y3 (Averting Activity)	33.350(0.334)
Constant	-210.350(-0.285)
Equation 3: Dependent Variable Y3 (Averting Activity)	
X1 (SPM exposure)	0.003(2.488)*
X2 (NO2 Exposure)	0.006(0.898)
X3 (Diseases)	1.107(2.582)*
X5 (Awareness)	0.006(0.175)
X6 (Annual Income)	0.00001(0.797)
Y1 (Sick Days)	0.509(2.544)*
Y2 (Medical Expenditure)	0.001(1.452)
Constant	1.569(2.052)*

*denotes t-statistics are significant at 5% level

Source: Obtained from E-Views Statistical Package

Note: The Value of the coefficients will change with the adoption of a more appropriate form of the health production function, which can be discussed further.

Table 7.7 Calculation of Marginal Willingness to Pay

Value of coefficients	β1	β7	β14	β2	β8	β15
Kolkata	0.087	0.764	0.003	0.076	0.145	0.006

Concluding Remarks

In Kolkata, by reducing one microgram concentration in SPM from its current level the annual welfare gain is Rs.17.68. In case of NO2, it is Rs.20.05. The estimates of annual welfare gain calculated in case of an unit SPM reduction for the entire urban population of

Kolkata is Rs. 54.05 million. Similar figures for NO2 is Rs. 61.30 million. However, the total damage to households in these two cities could be much higher than the damages from morbidity effects alone, which is reported here.

In India for instance, the budgetary allocation for environment is just about 1% and out of this the money allocated to air pollution control is very small. Similar figures for Kolkata as such are not available. Given the figures on welfare gain that is estimated in the present study, it can probably help policy makers to carefully set the air pollution abatement target policies and modify the health budgeting policies.

A1: Comparative Table of 2004- 2005 RPM

Id	Stations	Min_Dec04	Max_Dec04	Min_Dec05	Max_Dec05	Min_July04	Max_July04	Min_July05	Max_July05	Min_May04	Max_May04	Min_May05	Max_May05	Min_March04	Max_March04	Min_March05	Max_March05
1	Dunlop	198	267	190	260	47	47-73	32	68	73	109	70	97	85	204	71	256
2	Rabidra Bharati																
3	Ultadanga	215	286	220	279	53	53-67	52	64	62	100	70	109	94	198	105	227
4	Shyambazar	221	289	187	240	47	47-70	56	71	65	84	57	100	100	197	95	229
5	Saltlake	103	213	154	209	40	40-63	24	55	52	73	37	55	99	169	68	173
6	Paribesh Bhavan																
7	Beliaghata	198	235	172	210	38	38-61	38	51	47	78	45	79	90	196	89	211
8	Moulali	180	259	203	251	53	53-71	35	66	72	95	60	80	126	214	107	215
9	Raj Bhavan																
10	Hyde Road	189	253	174	241	37	37-80	39	61	54	79	55	80	66	173	63	234
11	Victoria Memorial																
12	Topsia	148	250	201	259	46	46-74	20	73	68	99	66	87	131	220	85	202
13	Mominpore	196	263	180	224	48	48-61	51	62	63	90	45	85	105	199	67	187
14	Minto Park	200	256	161	205	46	46-71	44	57	51	80	52	76	86	189	74	198
15	Gariahat	228	233	195	260	42	42-65	45	58	62	96	60	88	100	203	78	224
16	Picnic Garden	166	263	172	244	41	41-67	30	73	53	79	49	68	71	174	47	198
17	Baisnab Ghata	133	173	120	169	35	35-56	31	49	52	61	47	67	72	158	60	160
18	Behala Chowrasta	132	262	183	256	37	37-75	28	51	63	98	47	67	129	212	77	187
19	Tollygaunge	178	243	141	203	46	46-71	37	49	44	83	43	63	112	119	52	219

A2: Comparative Table of 2004- 2005 SPM

Id	Stations	Min_Dec04	Max_Dec04	Min_Dec05	Max_Dec05	Min_July04	Max_July04	Min_July05	Max_July05	Min_May04	Max_May04	Min_May05	Max_May05	Min_March04	Max_March04	Min_March05	Max_March05
1	Dunlop	344	439	342	421	110	181	71	84	210	248	186	237	223	390	115	408
2	Rabindra Bharati																
3	Ultadanga	336	460	250	290	116	166	94	178	188	249	153	231	254	369	169	367
4	Shyambazar	344	439	344	442	95	159	68	168	177	197	160	240	220	393	191	414
5	Salt Lake	197	340	267	344	88	153	44	156	140	207	117	175	229	316	188	342
6	Paribesh Bhavan																
7	Beliaghata	323	369	296	379	90	138	53	145	120	213	118	201	212	348	163	371
8	Moulali	284	404	320	408	106	158	72	181	181	242	160	216	260	389	251	401
9	Raj Bhavan																
10	Hyde Road	293	385	329	382	82	179	57	157	143	205	177	219	213	297	139	377
11	Victoria Memorial																
12	Topsia	250	395	351	415	110	173	46	188	178	242	157	222	287	383	288	408
13	Mominpore	322	397	297	386	103	152	82	164	178	232	162	214	258	395	148	343
14	Minto Park	319	413	254	354	92	154	66	156	159	200	137	209	228	357	151	352
15	Gariahat	358	373	324	419	98	156	62	162	12	226	156	225	233	366	178	383
16	Picnic Garden	287	395	289	370	80	155	64	157	134	210	157	203	202	324	71	350
17	Baisnab Ghata	240	298	231	296	83	130	59	141	115	188	106	173	183	282	141	284
18	Behala Chowrasta	261	399	300	374	94	185	51	165	157	247	152	200	251	377	221	380
19	Tollygaunge	299	395	250	338	92	167	51	146	159	202	130	193	252	369	91	371

A3: Comparative Table of 2004- 2005 NOX

Id	Stations	Min_Dec04	Max_Dec04	Min_Dec05	Max_Dec05	Min_July04	Max_July04	Min_July05	Max_July05	Min_May04	Max_May04	Min_May05	Max_May05	Min_March04	Max_March04	Min_March05	Max_March05
1	Dunlop	102	121	100	137	25	61	33	44	41	72	38	49	35	77	44	102
2	Rabidra Bharati																
3	Ultadanga	81	109	99	119	39	61	26	54	47	70	36	48	41	76	50	81
4	Shyambazar	86	109	79	120	21	61	32	42	37	63	34	43	42	86	38	85
5	Saltlake	44	98	72	93	21	43	23	37	28	62	26	40	28	74	38	70
6	Paribesh Bhavan																
7	Beliaghata	76	111	84	96	17	51	26	44	32	59	30	36	37	69	33	77
8	Moulali	66	128	84	141	42	64	32	50	44	100	37	56	58	90	54	92
9	Raj Bhavan																
10	Hyde Road	84	106	87	113	27	60	27	46	23	47	34	47	22	55	32	89
11	Victoria Memorial																
12	Topsia	76	118	80	118	26	54	21	45	45	85	36	52	29	89	46	88
13	Mominpore	83	103	84	111	37	51	30	40	39	54	31	43	30	68	39	80
14	Minto Park	84	103	71	118	38	49	42	46	37	61	33	44	32	63	37	72
15	Gariahat	90	123	99	121	28	59	36	59	29	91	37	46	37	79	40	90
16	Picnic Garden	80	99	81	106	21	61	27	37	28	66	27	38	30	55	28	78
17	Baisnab Ghata	62	73	62	83	25	39	24	36	22	37	26	34	36	58	38	61
18	Behala Chowrastra	59	109	84	127	28	64	27	44	38	85	33	49	39	90	48	79
19	Tollygaunge	85	106	74	110	30	64	25	40	40	83	31	42	31	80	42	83

A4: Comparative Table of 2004- 2005 SO2

Id	Stations	Min_Dec05	Min_July05	Min_May05	Min_March05	Max_Dec05	Max_July05	Max_May05	Max_March05	Min_Dec04	Min_July04	Min_May04	Min_March04	Max_Dec04	Max_July04	Max_May04	Max_March04
1	Dunlop	21	3	5	5	33	6	9	16	20	5	8	12	33	19	16	24
2	Rabidra Bharati																
3	Ultadanga	16	3	4	4	26	8	8	13	14	4	2	3	21	8	11	13
4	Shyambazar	13	3	4	5	23	5	6	14	12	3	2	6	26	8	15	22
5	Saltlake	8	2	2	3	16	3	5	9	5	2	2	3	14	6	3	18
6	ParibeshBhavan																
7	Beliaghata	13	3	4	4	17	5	7	17	15	2	2	5	23	7	7	16
8	Moulali	14	3	4	4	27	5	8	16	10	4	2	6	34	22	11	24
9	Raj Bhavan																
10	Hyde Road	14	2	4	3	21	4	7	12	12	2	2	4	20	6	9	12
11	Victoria Memorial																
12	Topsia	15	2	4	9	30	9	10	18	12	5	4	6	39	16	19	23
13	Mominpore	11	3	4	6	25	5	8	12	13	4	2	5	20	8	8	14
14	Minto Park	8	3	3	4	17	4	5	8	10	3	2	2	16	4	4	14
15	Gariahat	14	3	3	3	20	4	4	10	10	3	2	5	16	7	9	19
16	Picnic Garden	12	3	3	3	29	4	6	10	13	3	3	6	22	7	11	20
17	Baisnab Ghata	7	2	2	3	15	3	4	6	9	2	2	4	12	4	6	14
18	Behala Chowrastra	10	2	3	5	26	4	7	13	8	3	3	7	26	8	6	17
19	Tollygaunge	9	2	2	3	22	3	4	8	9	2	3	3	16	7	10	19

Chapter V

Recommendations

Methodologies for Preparation of Green Accounting in India

The methodologies that we suggest below are indeed based on the experience that we gathered while attempting to prepare green accounts for Air and Water Sectors for the State of West Bengal. Major source of data for us has been secondary official statistics available in the public domain and some case studies have been conducted. As mentioned in chapter I two following approaches:

- **Three Pillar Approach and**
- **Capital Approach**

both can be successfully followed in case of Indian economy as well as for the individual States. We summarise below our observations on what can be done and what kind of deliverables may emerge and how easily.

Observations on what can be done:

- **Through Three Pillar Approach**

1. With available data from secondary sources brought out by various agencies in India it is possible to follow **"three pillar approach"** to account for sustainable development. Given the long tradition of data collection, compilation and reporting in India this "three pillar approach" process can start immediately without any delay. (as an example what might the report can contain we enclose a 'Summary Report' prepared by us). Our summary report shows for all India but we probed and found that Same can be done for each state also. .
2. It is important to report sustainable development indicators-Composit sustainability index (CSI) along with macro economic indicators, GDP, HDI etc.
3. The Three pillar approach can lead to a concrete deliverable like "Sustainable Development Indicator Report". This can be thought of somewhat in the same form as "environmental statistics" report which is also a compilation. However,

sustainability report will have one more value addition of methodology applied to report CSI and just not the data.

General Recommendations are:

Composite Sustainable development indicators be prepared once in two years/annually to keep check on performance standard of the economy that goes beyond economic performance assessment. This will help in prioritization and reorientation in budgetary allocation, planning process and to mainstreaming of environmental issues and larger social goals along with economic goals.

The example of deliverable is attached summary report.

Observations on what can be done:

- **Through Capital Approach**

4. With available conceptual framework and data available it is possible to prepare physical account for water and air.
    a. For water it is possible to prepare stock account using IMD data
    b. For water, flow account in the form of SUT (Supply use table) can be prepared for economic activities.
    c. For air both stock and flow account can be prepared using rich data sets available from all monitoring stations of PCB (pollution control boards), NATCOM (National communication under UNFCCC obligation done from India By MoEF).
5. It is possible to publish "Resource Accounting Matrices" which can be compatible with basic I-O Table of India . But Resource accounting matrix will be in physical units. This kind of hybrid matrices are used in literature also (eg. NAMEA).
6. All above efforts can be annual or in two year interval.
7. However, these efforts are knowledge intensive, needs multidisciplinary approach and can be done using experts available across the country in various institutions.

But the major effort needs to be coordinated by Ministry of Statistics and Programme Implementation given it's expertise.

8. There is need for capacity augmentation by recruiting new young people who are trained in environmental economics or to train the existing SNA team. Several institutions in al the regions in India can extend their expertise on this. A list of institutions can be provided as and when needed.
9. Data collection and compilation need not always be in this regard centralized. Rather distributed efforts are fine but some coordination and standardization is needed. This can be done through targeted workshop conducted by experts. This will in fact generate a framework of how to collate data from various sources under the aegis of the government.
10. Monetary valuation process through maintenance cost estimates and damage cost analysis like health cost assessment, averting costs assessments for India are very crucial given that they capture human capital loss which can provide a good correction factor for Labour/ human capital which forms a major resource in India.
11. Given the trend of urbanization urban pollution related estimates for India , given the local problems e.g arsenic in West Bengal special assessments of local problems may get priority in report preparations to support policy planning. .

General Recommendations are:

1. We do not recommend replacement of current accounting framework for GNP/GDP calculation by Green GNP/Environmentally corrected GNP reporting before next five years. But we strongly recommend like many other countries e.g NAMEA or EU efforts it is important to start immediately the process of **satellite accounting process in physical units.**

2. The basic conceptual structure will be weak sustainability where we will try to report how Capital (portfolio) stock of the economy is changing .

a. Manmade capital (already reported in SNA)
b. Human capital and (already reported under HDI)
c. Natural capital (needs to be prepared through stock and flow account. This will indeed constitute the satellite account and needs to be reported independently initially and then pros and cons of mainstreaming will need to be discussed in brainstorming sessions.

3. For water we need to think of water quantity account and water quality account separately. First we make suggestions on Quantity account:
   a. To start with, water quantity stock account, be prepared for a base year.
   b. For flow account it can be SUT for smaller number of aggregate sectors which are usually reported in summary reports like Agriculture, Industry, Service, Residential and Commercial. As given in chapter 3 w can follow the SUT . The example of the framework is mentioned below . We can do this for India as well as for states. The sector breakup should gradually be done for I-O Table sectors but currently we do not have necessary data from any secondary source. Physical Water Supply and Use Tables (SUT) describe water flows in physical units within the economy and between the environment and the economy. The compilation of SUT allows for : (i)The assessment and the monitoring of the pressure on water quantities exerted by the economy (ii) The identification of the economic agents responsible for abstraction and discharge of water into the economy. (iii)evaluation of the alternative options for reducing water pressure.

Physical Water Supply and Use Table, (million cum)

Use Table

	agriculture	domestic	manufacturing	others	Total Use
Ground water					
Surface water					

Total use					

Supply Table

	agriculture	domestic	manufacturing	others	Total supply
Within economy					
Reuse					
Waste water to sewerage					
To the environment					
irrigation					
Lost in transport					
Treated waste					
Untreated waste water					
Total Supply					
Consumption					

Another layer of supply use table can also be prepared given the data availability i.e institutions wise e.g municipalities. Data are available with municipalities. These will provide with very good database for resource management and policy formulation.

c. For water quantity accounting in Indian situation another important framework can be adopted. Water body accounting can be done using satellite imagery. Google earth data is a rich source for identifying land use pattern change with respect to water bodies.

4. Water quality account should be in satellite account framework. All sectors (I-O) in rows and pollutants (BOD, COD, TSS) in columns. These will be in physical

units. Pollution load should be shown in physical units. Pollution load from each sector be shown as flows and there needs to be similar rows (BOD, COD, TSS) which will show new economic activities like abatement. If there is abatement /maintenance expenditure incurred by e.g paper and pulp industry then that amount should be shown an under paper industry column against BOD row. It would imply as if Paper industry has taken input from abatement activity sector. However, we do not think unless more complete information for all sectors are available it will not be advisable to adopt integrated accounting rather standalone satellite account needs to be prepared initially. All efforts need to be at all India level to start with. Such data det will help in environmental polic formulation also.

5. To start with, in air sector for GHGs which are stock pollutants stock account in physical units be prepared for a base year. This can be by all economic sectors as in I-O Table. For GHGs as well as Non-GHGs flow account be prepared by economic sectors for a base year in physical units.

6. All satellite accounting need to be basic I-O structure compatible.

7. Fow account which will start as satellite account i.e separate matrices compatible with economic sector breakup will eventually be integrated as abatement sector activity as row vector or change in stock in column vector.

8. Flow account of water and air quality be prepared using data of Pollution control boards, NEERI and call for data submissions which many agencies are doing may be used at the beginning. Later more systematic compilation through Pollution control boards/similar competent authorities may be decide upon. . The pollution is generally measured in terms of quantity of a measured parameter released during a certain period of time. They can be expressed directly in terms of quantity of parameter or reported to an arbitrary unit that can be represent one or more parameters. e.g in our case study we have shown how for pulp and paper

industry individual parameters like BOD , COD etc may be used vis- a- vis a water quality index (WQI) can be prepared and used.

9. Urban pollution causes discomfort or even worse it causes health problems. To obtain relief, inhabitants seek medical care. The practice in accounting is to regard expenditure on health as part of consumption. But it is current defensive expenditure against a loss of health. The expenditure on health theoretically should be included in natural capital investment as surrogate (albeit, not a perfect surrogate) for a missing item in national accounts: namely, health as a part of human capital. To arrive at economic valuation, case studies, will provide with the multiplier value for conversion of physical account into monetary accounting matrix. In arriving at the monetary unit we need to be careful about the methodology chosen. In the absence of market for environmental resources we need to decide in favour of maintenance cost approach. However, damage cost also need to be reported but separately to show the social value or social damage or demand price. In the absence of market supply price (the maintenance cost approach) is expected to diverge from demand price. Our water pollution related case studies show cost of drinking water quality maintenance through piped water in West Bengal is around (depending on whether rural or urban) Rs 127/- per household per month while damage cost is around Rs 297/- per household per month. For industry the water quality maintenance cost for 100 gms reduction in BOD is Rs 0.6- Rs112/- depending on scale of production. It will be difficult to choose only one value for maintenance cost. These uncertainties in estimates need ot be resolved before applying them as correction factor. Similarly for urban air pollution we found that in Kolkata, by reducing one microgram concentration in SPM from its current level the annual welfare gain is Rs.17.68 per household. In case of NO2, it is Rs.20.05. The estimates of annual welfare gain calculated in case of an unit SPM reduction for the entire urban population of Kolkata is Rs. 54.05 million. Similar figures for NO2 is Rs. 61.30 million. These represent the damage costs. However, the total damage to households could be much higher than the damages from morbidity effects alone. In India for instance, the

budgetary allocation for environment is just about 1% and out of this the money allocated to air pollution control is very small. Given the figures on damage cost for air and water that is estimated in the present study, it can probably help policy makers to carefully set the air pollution and water pollution maintenance costs as target policies and modify the health budget policies.

10. Such case studies for specific resources for specific select socio economic groups may be done at ten years interval through special dedicated sample survey. Repeated case study will be needed to take care of changing socio economic landscape, technology etc. To mainstream and make it a decadal practice for data update special NSSO rounds may be dedicated for the purpose with expert help else ASI data collection process and census data collection methods can be used. Else they can be specialized data collection method as NFHS data collection etc.
11. ASI data collection and reporting needs to be revisited. The fuel table should continue to report fuel consumption data in physical units as this provides very rich data set. Until 1979 they used to be reported annually , beyond that reporting in physical unit changed to five year interval and then after 2000 the physical unit reporting stopped and /or became irregular. It needs to be taken up with serious urgency as soon as possible.
12. ASI data on water purchase be extended to generate data on water use in physical units through water metering.
13. To strengthen water Supply use table and hybrid accounting it is important to meter all types of water use through out the country. This needs to be done with long term goal.

Barriers to overcome:

1. **In three pillar approach** it needs to be decided which minimum indicators we can adopt for India in preparation of sustainable development indicator. Then the data for those indicators need special monitoring, compilation and presentation to arrive at performance indicator. In our summary report we have taken the indicators based on currently available data sets but it needs be a consensus among experts, statistical department and policy makers.

2. Since data requirement in three pillar approach is varied but available in India one designated department within the ministry/institution led by an advisory committee be assigned the task to coordinate the effort and annual report publication.

3. Although the methods of generating national accounts have evolved over the decades, they are not perfect. Illegal activities are generally excluded. Housekeeping within the family is excluded. Value of the environment to the economy is also excluded, natural resources' value which do not consider user value and are reported based on distorted market value reflect wrong valuation. These have been the source of significant criticism over the past decades and currently they are emerging as major challenges. . Similarly, pollution is not included in the national accounts. Pollution is product like any other with two exceptions: it is not marketed and it has a negative value. All these call for global attention and action as well as how far standardization is possible need to be carefully examined. Some of the environmental resources are not locally owned rather they are regionally or globally owned.

4. Efforts for water account: both stock and flow must be entrusted with multidisciplinary research groups consisting of experts from various institutions spread over regions to get regional variety and special features and local knowledge. Given the current scattered data availability status it is a huge task. Moreover data cannot be gathered by private effort given the variety of institutions involved .once the base line information is gathered which is possible later efforts would become easier. During our

current effort given the time, manpower and money constraint we could collect some , got a hold on how to proceed but could not complete it comprehensively.

5. Access to IMD (Indian Meteorological Department) data on precipitation and temperature data are needed and then using evapotranspiration, run off and soil condition (Indian Soil Survey data) water stock account can be prepared. We started the process but given the nature of the task we could not really progress much with time constraint. We collaborated with hydrologists for the same to prepare the stock data. Human withdrawal data are needed to be supplied by the various government departments like Irrigation, Ground water board etc. Data access is not smooth right now. But if efforts are done at the initiative of the government ministry it may be easier.

6. Care has to be used when recording and allocating the pollutant load contained in the discharge of urban ran-off. Because water is highly polluted there is an increasing awareness in the potential danger if discharging urban ran-off into the environment without treatment. There has been efforts to recharge the ground water also with this run off water. But it will be difficult to identify the source of pollution load in urban water given then variety of activities and hence treatment activity (maintenance cost approach) how cost sharing can be done how much it can be distributed among dwellers is a difficult policy decision. Not only cost but also activity wise because it consists of urban transport liquid waste, domestic waste , commercial solid waste degraded into liquid waste etc.

7. The actual adjustment to state level domestic product will have to be discussed and needs to be adopted nationally or globally. This will have serious implication so cannot be done in haste.

8. While some of the maintenance costs are already reflected in the state or national accounts without making specific mention so to avoid double counting care needs to be taken both at the conceptual and practical level. The problem can be solved by revisiting

sector disaggregation or aggregation. Specific examples can be used to demonstrate possible solutions.

9. Spatial data through GIS mapping must be made mandatory and all the resource data can then be mapped in the same grid scale to make landuse planning sustainable. Land is one kin dof natural capital so capital theoretic approach can achieve the goals the best using GIS data successfully.

In conclusion it may be said that work can start on Sustainability index preparation and reporting for India Natural on Resource accounting in satellite accounting framework under the leadership of Ministry of Statistics and Programme Implementation with a dedicated team for this purpose under the guidance/consultative support of experts from Indian institutions across regions. However, calculation of Green GDP or Environmentally corrected GDP for reporting is not advisable at this stage. There can be a five year target. During these five years Sustainability Report, Satellite Resource Accounting Report for Air and Water can be prepared on a consensus framework which will be reviewed after five years to decide how corrected measure can be prepared taking global efforts and examples into consideration.

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