Draft not to be quoted

Water pollution in India: an Input-Output Analysis

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Paper submitted for the 20th IIOA conference to be held at Bratislava, June 25-29, 2012

Abstract

India, being a rapidly growing economy, has to resolve massive environmental problems. The direct consequences of the process of development and the range of issues categorized as environmental problems include industrial pollution (i.e. pollution of air, water and soil) vehicular emission, hospital waste and domestic sewage disposal etc.

Water pollution has emerged as one of the gravest environmental threats to India. In India, every year, approximately, 50,000 million litres of waste water both industrial and domestic, is generated in urban areas. The govt. of India is spending millions of dollars every year on water pollution control. According to rough estimates, Indian government has spent nearly 4450 million USD till now on various schemes in India, like the Ganga action plan and Jamuna action plan to control water pollution in rivers. But the results are below satisfaction.

Water quality and pollution level are generally measured in terms of concentration or load – the rate of occurrence of a substance in an aqueous solution. BOD (Biochemical oxygen demand) measures the strength of an organic waste in terms of the amount of oxygen consumed (by the micro organism in water) in breaking it down. This is a standard water treatment test for the presence of organic pollutants. Moreover, a number of physical and chemical parameters (which defines the water quality) such as Ph, DO (dissolved Solids), total Solids, inorganic trace elements are quite large that also needs to be monitored for proper assessment of water quality.

A significant number of industries (for example, Livestock, Oil Refineries, Coal & Lignite, Chemical industries, Distilleries, Manmade fibre, Paints & Dye, Leather, Textiles, Paper, Fertilisers, Milk & Milk Products) in India are producing water pollution above MINAS by several times. These industries do not exist in isolation from each other, rather are inter dependent. This inter dependence arises from the fact that the output of an industry is generally required as an input by another industry. Though some industries do not produce pollution directly but these industries produce pollution indirectly in a significant way.

A number of industries in India are minimizing water pollution generation in recent periods. Even if a single industry, for example, Chemical industry tries to control the pollution generated by it, production cost is bound to increase. Such an increase in production cost will affect the market price of the product of Chemical industries. Since the product of this industry is being used by other industries, these will also be affected which, in turn, will influence the prices of all the sectors. Pollution Control Scheme will also impact the demand for output of different products which are used as inputs in the above schemes. Thus the Pollution Control Scheme influences the output and prices of different industries.

Though a considerable number of studies have been conducted on water pollution in India but a quantitative analysis involving interdependence between water pollution and all branches of production and consumption of an economy is hardly any.

The current paper constructs a detailed water pollution coefficient matrix involving different types of water pollutant such as BOD, COD, SS, DO, Zinc etc using different sources available from Central Pollution Control Board of India. An Input-Output model is developed to link between water pollution generated by different industries and the various economic activities of the Indian economy for the year 2006-7. The paper estimates the total amount of water pollution generation directly and indirectly from different sectors/ activities of India. Analysis of the results indicates the variation in the pollution content of different economic activities of India. The paper also suggests some policy options to address the water pollution problem.

1. Introduction

Water pollution is the presence of harmful and objectionable material in water in sufficient concentration to make it unfit for use. Water contamination weakens or destroys natural ecosystems that support human health, food production and biodiversity. Water –borne diseases kill millions people worldwide every year. Likelihoods such as agriculture, fishing and animal husbandry are affected by poor water quality. Biodiversity, especially of freshwater ecosystems is under threat due to water pollution.

Water is very important to life and polluted water is a huge concern. Polluted water can lead to serious problems with disease and death of plants and vegetation, humans and animals. Water pollution prevention helps to ensure that there is enough clean water to allow for healthy growth and development of the earth, humans and animals. Prevention and control of water pollution assures that the water can remain safe for consumption of plants and vegetation, humans and animals.

India's 14 major, 55 minor and several hundred small rivers receive millions of litres of sewage, industrial and agricultural wastes. The most polluting source for rivers is the city sewage and industrial waste discharge. Presently, only about 10 per cent of the waste water generated is treated; the rest is discharged as it is into our water bodies. Due to this, pollutants enter rivers, lakes and groundwater (CAG,2011).

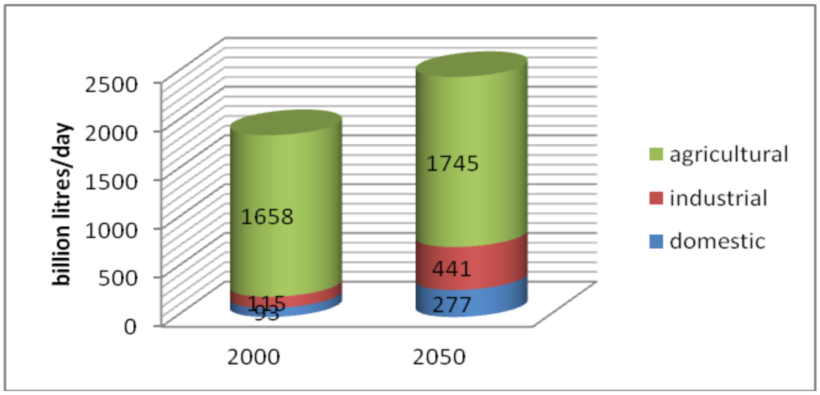
Such water, which ultimately ends up in our households, is often highly contaminated and carries disease-causing microbes. Agricultural run-off, or the water from the fields that drains into rivers, is another major water pollutant as it contains fertilizers and pesticides. Ground water accounts for nearly 80 per cent of the rural domestic water needs and 50 per cent of the urban water needs in India. It is generally less susceptible to contamination and pollution when compared to surface water bodies.

Numerous human activities including agriculture, industry, mining, disposal of human waste, population growth, urbanisation, climate change etc. impact water quality. Agriculture can cause nutrient and pesticide contamination and increased salinity and nutrient enrichment has become one of the most widespread water quality problems of the planet.

Freshwater Scenario in India

Traditionally, India has been well endowed with large Freshwater reserves, but the increasing population and overexploitation of surface and groundwater over the past few decades has resulted in water scarcity in some regions. Growth of the Indian economy is driving increased water usage across sectors. Wastewater is increasing significantly and in the absence of proper measures for treatment and management, the existing Freshwater reserves are being polluted. Increased urbanization is driving an increase in per capita water consumption in towns and cities. Urbanization is also driving a change in consumption patterns and increased demand for water-intensive agricultural crops and industrial products.

Water consumption in India



Source: 'Water for People Water for Life', United Nations World Water Development Report, 2003; 'The Global Water Crisis: A Question of Governance', Policy Research Division, Department of Foreign Affairs and International Trade Canada; 'Statistical Yearbook for Asia and the Pacific 2007', United Nations Economic and Social Commission for Asia and the Pacific; 'India's Water Future to 2025 –2050: Business as Usual Scenario and Deviations', International Water Management Institute; OS-Connect Database; US Geological Survey -Water Resources; Aquastat Database

Water consumption in Indian agriculture

Available resources are likely to be overexploited with a rise in the consumption of water for irrigation. India is one of the world's leading crop producers. Over the years, this has led to an increase in water consumption in the agricultural sector .Consumption of water for irrigation is rising. The volume of water used for irrigation in India is expected to increase by 68.5 Tr liters between 2000 and 2025[1].

Wheat, Rice and Sugarcane together constituted 91% of India's crop production (food grain and sugarcane) in 2008. Wheat production in India has increased from 76.4 million Metric tons in 1999-2000 to 78.4 million metric tons in 2007-8(CAGR 0.34%); while rice production increased from 89.7MMT in 2000 to 96.1MMT in 2007-8(CAGR 0.87%) and sugarcane production in India has also increased from 299.3 MMT to 340.6 MMT in 2007-8(CAGR 1.63%)(FAO Corporate Document Repository). Virtual water consumed for production of wheat, rice and sugarcane

[1] 'India's Water Future to 2025 –2050: Business as Usual Scenario and Deviations', International Water Management Institute

has increased by 88 Tr liters over the period 2000 to 2008- for Wheat it increased by 4 Tr liters; for Rice it increased by 18 Tr liters; for Sugarcane it increased by 66 Tr liters[2].

Demographic and economic factors are driving the use of water in agricultural production.

Rise in domestic demand for food grains: India's demand for food grain will grow from 178 MM mt in 2000 to 241 MM mt in 2050. Increase in exports: Value of agricultural exports of India have tripled from $5.6 Bn in 2000 to $18.1 Bn in 2008. Change in consumption pattern of agricultural products: Demand for agricultural products with high water footprint is projected to rise with increased disposable income and urbanization. Contribution of non-food grain (sugarcane, fruits and vegetables, etc.) and animal products (livestock and dairy products) in daily food intake for an individual is expected to grow from 35%(total daily calorie intake) in 2000 to 50% 2050[3].

Agricultural production growth is leading to greater water stress

Rise in water consumption: Rice, wheat and sugarcane together constitute 90% of India's crop production and are the most water-consuming crops. India has the highest water footprints among the top rice and wheat producing countries. Increase in wastewater discharge: Agriculturally based industries such as textiles, sugar and fertilizer are among the top producers of wastewater[4].

Water consumption by Industries

Industrialization and infrastructure growth are projected to drive water consumption and lead to increased discharge of untreated wastewater.

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[2] Status of Virtual Water Trade from India', Indian Academy of Sciences; Reserve Bank of India publications; FAOSTAT

[3] Reserve Bank of India publications; 'India's Water Future to 2025-2050', International Water Management Institute; 'Changing Consumption Patterns: Implications on Food and Water Demand in India, International Water Management Institute; 'Water footprints of nations: Water Use by People as a Function of Their Consumption Pattern', Water Footprint Network; 'Mapping Water: Scarcity and Pollution', Center for Science and Environment

[4] 'Dynamic Groundwater Sources of India', Ministry of Water Resources, 2006; Reserve Bank of India database and publications; 'Spatial Variation in Water Supply and Demand Across the River Basins of India ', International Water Management Institute, 2003; Proposal to Introduce Direct Power Subsidy to Farmers', The Indian Express Newspaper, June 2008

Growth drivers for Water intensive industries

FDI equity inflow in the industrial sector has grown from $1.93 Bn in 2004–2005 to $17.68 Bn in 2007–2008. Steel and electricity dependent industries are expected to grow in the coming years. Between 2006 and 2010, investment in infrastructure development was 7.7% of India's GDP. The manufacturing sector grew at an average of 8.6% between 2002 and 2007 and is expected to grow at 9.5% per annum in 2008-09. Thermal power plants (the most water-intensive industrial units), constituted 64.6% of the installed power capacity in India during 2008. Steel production in India has increased from 37 Million metric tons to 52.7 million metric tons (CAGR 8.1%). Electricity generation in India has increased from 558 to 704 Billion Kwh from 2003 to 2007(CAGR 6%). Annual per capita consumption of power is expected to grow from 704.2 Kwh in 2008 to 1,000 Kwh by 2012. 75% of the total planned power capacity expansion is projected to come from thermal power.

Impact on water stress

Industrial water consumption is expected to quadruple between 2000 and 2050. Industrial water consumption will reach 18% of total annual water consumption by 2050, up from just 6% in 2000. Industrial wastewater discharge causes pollution and reduces available freshwater reserves. 6.2 Bn liters of untreated industrial wastewater are generated every day. Thermal power plants and steel plants are the highest contributors to annual industrial wastewater discharge.

Increased disposable income and urbanization is projected to change consumption patterns towards more water-intensive products. India's annual domestic per capita consumption (kg) of water intensive products like poultry meat, egg, cotton and milk is increasing. During the period 2000-2020, chicken and milk production is projected to grow at a CAGR of 3% and 4% respectively. Production of cotton is expected to grow at a CAGR of 1.6% during the period 2000-2025.

In a large developing country such as India, the links between water consumption across sectors complicates water management. Increased agricultural income is leading to increased urbanization and changing water consumption patterns.

Rapid industrialization and unplanned urban growth is resulting in the generation and discharge of large quantities of wastewater into existing water bodies.

India has an inadequate treatment infrastructure. Only 26.8% of domestic and 60% of industrial wastewater is treated in India, Wastewater management plants in cities have a capacity of approximately 6,000 MM liters per day , 423 Class I cities treat just 29.2% of their wastewater, while 499 Class II towns are able to treat just 3.7% of wastewater due to poor treatment infrastructure . The waste water generation was 15,438 million litres/day in 2003, out of which 6175 million litres/day untreated and 9263 million litres/day treated. Delhi, the national capital, treats less than half of the 3,267 MM liters of wastewater it generates every day. Sometime the use of untreated wastewater for irrigation leads to the reduction in agricultural production (e.g. in Hyderabad, wastewater drawn from the river Musi for irrigation has reduced rice output by 40-50%)[5].

Discharge of untreated wastewater is leading to increased pollution and depletion of clean water resources. In this background, the current study estimates the generation of water pollution from Indian industries for the year 2006. An Input-Output model is developed to link between water pollution generated by different industries and the various economic activities of the Indian economy for the year 2006-7. The paper estimates the total amount of water pollution generation directly and indirectly from different sectors/ activities of India. Analysis of the results indicates the variation in the pollution content of different economic activities of India. The paper also suggests some policy options to address the water pollution problem.
Rest of the paper is organized as follows. Section 2 briefs some review of literature. Methodological presentation is given in section 3. Construction of pollution data and other data

[5] Sustainable Technology Options for Reuse of Wastewater', Central Pollution Control Board; 'Wastewater Management and Reuse for Agriculture and Aquaculture in India', CSE Conference on Health and Environment 2006; 'Wastewater Reuse and Recycling Systems: A Perspective into India and Australia', International Water Management Institute

information is provided in section 4. Section 5 analyses the results. Section 6 concludes the paper with some constructive suggestion.

2. Literature Survey

Literature in this field is weak. Most of the studies dealt with the abatement cost of water pollution as well as the impact of fiscal policies on water pollution using econometric analysis. We have discussed some of them. The study by James and Murty (1996) has estimated marginal abatement cost using plant level data of 82 firms drawn from 17 major polluting industries identified by the Central Pollution Control Board (CPCB) of India. This study has used the ratio of influent and effluent concentration in the cost function. Pandey (1997) has made an attempt to estimate abatement costs by analysing plant level data on costs of water pollution abatement in sugar industry for 53 firms. The Cobb-Dougals functional forms are used in estimating the abatement cost functions. The analysis point out the loophole in the existing legislation (MINAS) and suggests the pricing of water be rationalised. Further, pollution tax would require periodic revision based on consideration such as firms, response, and inflation advent of new technology. Also, as pollution causing activity rises and source specific standards are more stringent in order to maintain the same ambient standards, pollution tax will have to be revised from time to time. Study by Roy and Ganguli (1997) attempts to evaluate the efficiency of the standards for controlling BOD and COD of large pulp and paper mill effluent to maintain water quality. Using secondary data on water pollution audit by BICP for large pulp and paper mills, an attempt has been made to estimate marginal cost of abatement curves of BOD-5 and COD of different firms. An engineering cost function has been estimated using OLS estimator. The focus of Goldar and Mukherjee's (1998) paper is on methodological and estimation issues for water pollution abatement cost function. They have also suggested an alternative approach to specifying the production function for abatement activity that avoids all these problems and derive the associated cost function.

The study by Misra (1998) provides empirical evidence on economies of scale in water pollution abatement activity at Nandesari Industrial Estate comprising 250 small-scale factories. The study shows that the cost burden of water pollution abatement is much higher for small factories providing greater cost advantage to treat effluents jointly in a Common Effluent Treatment Plant (CETP). Further, clean water production as resultant of environmental deterioration, clearly has an adverse impact on human welfare.

Dasgupta and Murty (1985) explore some problems related to the control of external diseconomies (damages) inflicted on water resources by various developmental activities. Their study has shown that paper and pulp industry in India contributes significant environmental pollution which requires additional resources to abate it. Estimates of costs of water pollution abatement for big and small paper mills show that the comparative capital and operation costs per tonne of paper for the small paper mill is more than double that for the big mill. Pollution abatement costs for big and small paper mills at shadow prices are significantly higher than those at market prices. The estimates of pollution abatement costs of paper mills at shadow prices reveal returns to scale. James and Murty (1996) have suggested the use of incentives based policies as the most efficient technique for the control of environmental pollution. Resosudarmo (2003) analysed the data from global environmental monitoring activities and have shown the alarming environmental conditions in many developing countries. Environmental policies that could improve the environment significantly, while at the same time maintaining the growth of economic activities are needed. Using an input-output analysis, this paper researches such policies with a view to applying them to Indonesia's river water pollution. Firstly, this paper reviews river water quality and current policies in Indonesia. Secondly, it develops future policies to control such pollution. Barua and Hubacek (2009) tried to exploretThe Environmental Kuznets Curve (EKC) relationship for water in India. The study contributes to the EKC debate by using per capita income and water quality indicators for 16 states of India along with a variety of relevant explanatory variables. Using a panel data set for 20 years (1981-2001) they apply both the Generalised Least Square (GLS) and Arellano-Bond Generalised Method of Moments (GMM A-B) econometric methods. They found no evidence in support of the EKC hypothesis. Overall, they found that the decline in pollution during the process of economic growth is only temporary, as it tends to rise with further income growth.

Population density, livestock population and literacy are found to have strong effects on the water quality of the rivers of India.

But a quantitative analysis involving interdependence between water pollution and all branches of production and consumption of an economy is only few. Maiti and Chakraborty (1999) have studied the amount of different types of water pollutant generated directly and indirectly in different industries of India for the year 1989-90. Further, they have also studied the effect of cost of pollution control on the economy. The current study is also exercised in that direction using input-output table for the year 2006-7.

3. The Methodology

The frame work is an extension of the basic Input-Output model of Leontief. Input-output model primarily deals with methodology of analysing interdependence among the different sectors of the economy. Thus it becomes a tool to measure inter-sectoral, inter-relationship. In input-output analysis, the economy is broken up into sectors and flows of goods and services among these sectors are recorded, to study the relationship among them in a systematic and quantitative manner.

3.1 The Basic Input-Output Model

The basic Input-Output model can be explained by considering a simple hypothetical economy consisting of ‘n’ sectors. These ‘n’ sectors would be interdependent in so far as they would purchase inputs from and sell outputs to each other.

The Input-Output matrix presents inter-industry flows of intermediate inputs among the various sectors of the economy. A column records all the inputs required from the various sectors in the production process of a particular activity, while a row describes the material flows from a particular sector to different sectors. A technology coefficient matrix is derived from the input-output transaction matrix by dividing all elements in the input column by the output level of a sector represented by the column. Thus, if A = (aij) is the input-output coefficient matrix, then a typical element ‘aij’ represents the amount of input ‘I’ required to produce one unit of output ‘j’. The direct input-output coefficient matrix is of course, the core of the model. Since total output is equal to inter industry sales plus final demand, we have

$X = AX + Y$ (3.1)

From which

$X = (I - A)^{-1} Y$ (3.2)

is easily derived. This gives the solution for the output vector ‘X’ given the final demand vector ‘Y’ and the technical matrix ‘A’.

Here

A = n X n matrix of input-output coefficient matrix

X = n X 1 vector of output

Y = N X 1 vector of final demand

I = n X n identity matrix

3.2 Pollution Model

The input-output framework has been extended here to account for water pollution generation.

To study water pollution generation associated with interindustry activity let us consider a matrix of pollution output coefficient, denoted by, W [Wkj], each element of which is the amount of water pollutant type ‘K’, (for example, chloride, sulphide) generated per Rupee's worth of industry ‘j's’ output. Hence, the level of water pollution associated with a given vector of total outputs can be expressed as

$R = WX$ (3.3)

Where R is the vector of pollution level. Hence by multiplying the traditional Leontief's inverse matrix (I-A)-1, we can compute R' that is, the total pollution of each type generated by the economy directly and indirectly by different sectors.

$R' = W (I - A)^{-1}$ (3.4)

Here R' is the direct and indirect water pollution coefficient matrix of different sectors (K X n)

W is the direct water pollution coefficient matrix of different sectors (K X n)

$(I - A)^{-1}$ is the Leontief matrix multiplier of different sectors (n X n).

4. Data

To work into the various types of water pollutants generated by the different industries of India with the help of the methodology as developed in previous section we need appropriate data. The present study is based on the secondary data. The major data required for the work are 1) the Input-Output tables and 2) different types of water pollutants generated by the different industries of India.

4.1 Input-Output Data

The study has used the input-output table of India for the year 2006-7 recently published prepared by the CSO (2011). The Input-Output tables of 2006-7 consist of 130*130 sectors. For the sake of convenience the input-output tables have been aggregated into 38 sectors respectively. The list of the sectors is shown in table 4.1. Sectors which have a relatively high level of water pollution generation (Livestocks, Oil Refineries, Leather, Paper, textiles, dairy products, Chemicals, Food products etc.,) are presented as separate sectors. But the other sectors have been aggregated.

Table 1 List of the sectors for the year 2006-7	
1. Agriculture	20. plastic prod
2. other agriculture	21. Petro-coal tar products
3. Milk and milk products	22. Inorganic heavy chemicals
4. livestock	23. Organic heavy chemicals
5. fishing	24. Fertilizers

6. coal and lignite	25. Pesticides
7. mining and quarrying	26. Paints, varnishes and lacquers
8. sugar	27. other chemicals
9. Oil and vanaspati	28. Synthetic fibers, resin
10. Tea and beverages	29. other non-metallic mineral
11. Food product	30. Iron and steel
12. cotton text	31. Machinery and metal products
13. woolen and silk text	32. Electrical machinery
14. jute hemp Mesta	33. transport equipment
15. miscellaneous textile prod	34. other machinery
16. wood and wood products	35. construction
17. paper and paper products	36.Electricity gas and water supply
18. Leather and leather products	37. transport service and communication
19. Rubber prod	38. Other services

4.2 Water Pollution Data

Data on water pollution are scanty and are not available in the required form. However, Central Pollution Control Board (CPCB) and Bureau of Indian Standard (BIS) publish certain documents which have been of great use in attaining different types of water pollutants generated from different industries. We have obtained 10 types of water pollution data (CPCB, 2006). The work is constrained by the fact that the sectors mentioned in these documents have to be dealt, corresponding with input-output classification. Water pollutants generated by the different Indian industries are mentioned below

1. Suspended solids (SS); 2. Dissolved solids (DS); 3. Chloride; 4. Sulphide; 5. Zinc; 6. Phenol

7. Oil and Grease; 8. Biochemical Oxygen Demand (BOD); 9. Chemical Oxygen Demand (COD); 10. Other Pollutants such as nitrogen, chromium, cyanide, Alkalinity, etc.

Data for 38 sectors were not available. First of all, these 38 sectors classification will give us not only direct pollution status but also indirect pollution. Secondly, it is quite likely that water pollution not directly generated from all 38 sectors as for example, service sectors, communication, equipments, transports etc. In that case the 38 sector classifications will provide a good view of indirect contribution.

Derivation of Different Types of Water Pollutants

We have used some of the water pollutant data for some sectors (textile, paper, chemicals, machinery, etc.) directly from the documents published by central pollution control board. But for the rest of the sectors, these data have been calculated on the basis of available information following the procedure mentioned below. For each sector the following information of pollution generation have been collected

a. Flow of waste water (F) = $\dfrac{\text{Amount of waste water in litre}}{\text{tonne of production}}$

b. Amount of different types of water pollutants (W) Per Litre

$$= \frac{\text{Amount of different types of pollutants (in milligrams)}}{\text{litre of waste water}}$$

c. total amount of production of each sectors(P) in tones

From these parameters we have been able to derive the total amount of different types of water pollution generation by different sectors, by the following steps

1. Total amount of waste water flow in litres (F/) F/ = F*P

2. Total amount of each types of water pollutants (W/) W/ = F/*W

To illustrate the method of calculation of pollution generation of composite industry we use the beverage industry can be used as an example. Beverage industry is a composite industry comprising of many units, but due to our limited availability of data we have used Soft Drinks, Maltries, Breweries and distilleries industries as representative of the sector. Here, the combined waste water characteristics have been derived by giving weights, with respect to their production level and then arriving at an average for the four industries considered for the specified sector i.e., Beverages. It has been so done due to non availability of data on the other industries, as is the case for Tea & Coffee processed industry. Similar method has been used for the other composite sectors, such as Other Food Products (represented by Fruits & Vegetables, Bakeries, and Confectioneries), Drugs & Other Chemicals (Drugs & Medicine), Non metallic minerals (Structural clay) and Electricity water gas supply sector (thermal power plant).

4.4 Unit Used

This work has been done in hybrid units. Sectors are treated in value units (Lakh Rs.) and the different types of water pollutants generated are treated in physical units ('000 tonnes).

4.5 Construction of the Matrix of Water Pollutants

Ten types of water pollutants generated by the industries of the Indian economy, here we have presented the seven types of pollutants in table 2. Table below shows the percentage share contribution of water pollution by selected industries in 2003. We have focused on the sectors having share with a decimal point. According to the CPCB document (2003), the highest Suspended solids, is generated by electricity sector (95% approximately). Thermal power plants contribute to atmospheric pollution by discharging fly ash, smoke, gases of oxides of sulphur, carbon and nitrogen. Over 12 million tonnes of fly ash are generated (Iyer, 1986) from thermal power station which is mostly dumped in nearby rivers and lakes causing pollution. Fly ash contains toxic metals, zinc (6%), barium (12.2%), vanadium (.08%), copper (1.3%), arsenic (0.02%), manganese (0.23%), thalium (1.2%), phosphorous, sulphur and silica. It also produces water pollution [CPCB, (PROBES/51/1993-94)] to the extent of 139546 thousand tonnes of suspended solids, major part of which constitutes of fly ash. Rest of the sectors having less than 1% share are Milk & Milk Products, livestock, paper and paper products, textile, iron and steel generated .

For dissolved solids, the shares of the important sectors ranges from 12-16% such as milk and milk products, cotton textile, woolen and silk products, leather and leather products, and chemicals.

Chloride is generated by particular plants such as textiles sector (except cotton), leather and partly from iron and steel.

Sulphide is primarily generated by the other textiles sector except cotton. Oil and grease is mainly generated by Petroleum and coal tar products, organic heavy chemicals, milk products and livestock. Phenol and ZINC is not so important compared to other water pollutants in the Indian economy.

The similar calculation has been done for the other sectors of the Indian economy. BOD (Biochemical oxygen demand) and COD (Chemical Oxygen demand) measure the strength of organic and chemical waste respectively, in terms of the amount of oxygen consumed (by the microorganism and chemical present in water) in breaking it down. These are a standard waste water treatment test for the presence of organic and chemical pollutants. The reliable estimate of BOD can be made after 5 days whereas COD can be estimated within two hours. BOD and COD are released from almost all the sectors in the economy.

It appears from the table that BOD and COD content are reasonably high in livestock sector. Rest of the sectors having highest share is common for both the pollutants. The sectors are Milk & Milk products, different types of textiles, paper and paper products, chemicals, machinery, leather products etc.

Table 2 Contribution of water pollution from different industries (% share)

	SS		DS		Chloride
Milk and milk products	0.236279223	Milk and milk products	12.17494195	Milk and milk products	1.62915952
livestock	0.677627479	sugar	3.427844508	woolen and silk text	17.15265866
mining and quarrying	0.138146849	Tea and beverages	2.69723119	jute hemp mesta	22.05831904

sugar	0.23299394	cotton text	16.51535484	mics textile prod	30.87993139
cotton text	0.143920151	woolen and silk text	14.24282089	Leather and leather prod	19.29674099
woolen and silk text	0.329902924	mics textile prod	1.966821004	Pesticides	3.12864494
jute hemp mesta	0.189006883	Leather and leather prod	14.18746755	Iron and steel	5.859691252
mics textile prod	0.247427193	Rubber prod	5.030552251		
paper and paper prod	0.410316762	plastic prod	2.056706705		
Leather and leather prod	0.265984232	Inorganic heavy chemicals	14.74607924		
Organic heavy chemicals	0.110496861	other chemicals	12.94963481		
Fertilizers	0.22694572				
Pesticides	0.061856798				
Iron and steel	0.672177207				
Electricity gas and water	94.98543				

	Sulphide		Oil and grease
woolen and silk text	18.73777004	Milk and milk products	8.803734963
jute hemp mesta	30.63218059	livestock	13.6706877
mics textile prod	39.91959704	sugar	0.869971157
Leather and leather	0.362535116	Oil and vanaspati	2.214691674

prod			
Rubber prod	0.828372373	Food product	0.469917306
Petro coal tar prod	9.024272989	woolen and silk text	1.026140476
Iron and steel	0.494106849	jute hemp mesta	0.335854637
		mics textile prod	0.463071895
		Petro coal tar prod	59.08394715
		Organic heavy chemicals	11.46404945

	BOD		COD
Milk and milk products	5.740645823	Milk and milk products	7.663920277
livestock	28.39876986	livestock	29.70160821
fishing	0.018657099	fishing	0.022532594
sugar	8.180420297	sugar	0.924473525
Oil and vanaspati	1.906714505	Oil and vanaspati	0.224167453
Tea and beverages	1.333849308	Tea and beverages	1.45601684
Food product	0.045310097	Food product	0.043848776
cotton text	2.549461814	cotton text	3.034080404
woolen and silk text	5.125576627	woolen and silk text	7.646021636
jute hemp mesta	3.587903639	jute hemp mesta	3.996784037
mics textile prod	5.945668888	mics textile prod	7.402739129
paper and paper prod	5.398769862	paper and paper prod	5.850654662
Leather and leather prod	1.949769349	Leather and leather prod	2.693484894
Rubber prod	1.767811379	Rubber prod	1.549014474

plastic prod	0.276781138	plastic prod	0.390989743
Petro coal tar prod	1.438236802	Petro coal tar prod	5.887147038
Inorganic heavy chemicals	0.922603793	Inorganic heavy chemicals	1.546581649
Organic heavy chemicals	7.534597642	Organic heavy chemicals	4.731844753
Pesticides	0.891850333	Pesticides	2.293806491
Paints, varnishes and lacquers	0.722706304	Paints, varnishes and lacquers	0.051089326
other chemicals	1.783700666	other chemicals	5.751893549
Iron and steel	3.352127114	other non metallic mineral	0.174028086
Machinery and metal prod	3.690415172	Iron and steel	4.726631557
other machinery	7.380830343	Machinery and metal prod	0.6488692
		other machinery	1.297564626
		Electricity	0.290201

The Extended Input-Output Table

We prepare an extended input-output table of different sectors with total amount of different (10) types of pollutants generated by different industries of Indian economy in the year 2006-7.

5. Experiment with Model: The Results and Discussion

This section attempts towards making a discussion on the results derived at through application of the methodology (Model I) described in section 3 based on the data analysed in section 4.

Direct and Indirect Pollution Output Coefficient

We have estimated the direct, total (direct and indirect) water pollution generation coefficients of different sectors respectively for the year 2006-7. The ten sets of pollution output coefficient that make up matrix W used in the computation. As it is well known, the inverse $(I-A)^{-1}$, where A represents structural (input coefficients) matrix of a given economy describes the total i.e. direct and indirect, effect of " one Lakh Rupees " worth increase in the final demand for the products of any given industry on the total output of this and every other industry. The amounts of each one of the ten different kinds of water pollutants generated in connection with the increase in level of all output contributing directly or indirectly to deliver to final uses of one “Lakh Rupees" worth of each particular kind of good are represented accordingly by the matrix product, $W * (I-A)^{-1}$.

In other words, direct and indirect water pollution coefficients of the Indian industries are given by the matrix product $R' = W * (I-A)^{-1}$

Here R’ is the direct and indirect water pollution coefficient matrix of different sectors (10 X 38)

W is the direct water pollution coefficient matrix of different sectors (10 X 38)

$(I-A)^{-1}$is the Leontief matrix multiplier of different sectors (38 X 38)

We noticed that for all industries, total coefficient is significantly higher compared to the corresponding data in direct coefficient. The sectors having zero direct coefficient signifies that the sector is non polluting, however, the corresponding non-zero entry in total coefficient stresses that though the sector is non polluting, it indirectly participates in the overall pollution generating machinery.

As for example, due to lack of data some sectors such as Transport and communication, other Services, electrical machinery are assumed to be non- polluting in these exercises. But however the total pollution coefficient stresses that though the above sectors are assumed non-polluting, they indirectly participate in the overall pollution generating machinery (through the inputs it uses). For example, direct total pollution generation in transport and communication is assumed to be absent but indirectly (through the inputs it uses) it generates pollution indirectly at the rate of 0.0003314,0.0000037,0.0000008,0.0000011, 0.0000145 thousand tonnes of suspended solids(SS), Dissoved Solids (DS), Oil and Grease, BOD and COD respectively per Lakh Rupees of the products of these sectors. Figures 1 through 4 present the direct coefficient of four important water pollutants –DS, SS, BOD and COD. These figures capture top six highest coefficients releasing from the sectors. The highest coefficient of DS generated by leather products sector, while for Suspended Solids is electricity. Inorganic heavy chemicals, beverages, textiles rubber products, leather and paper products are also in the top six lists of these two pollutants. An interesting feature is noticed for the direct coefficients of BOD and COD. Out of top six sectors, four sectors are common in these pollutants- jute hemp mesta textiles, tea and beverages, livestock and pesticides. Apart from that sugar and organic chemicals from BOD and Leather and woolen textiles in case of COD is observed.

Figure1

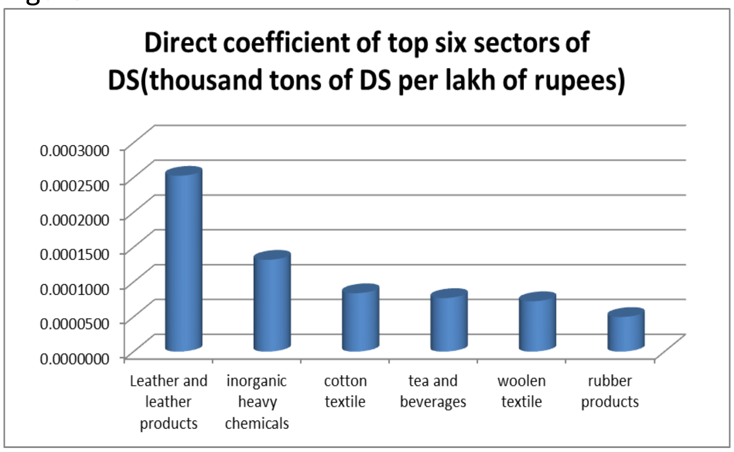


Figure 2

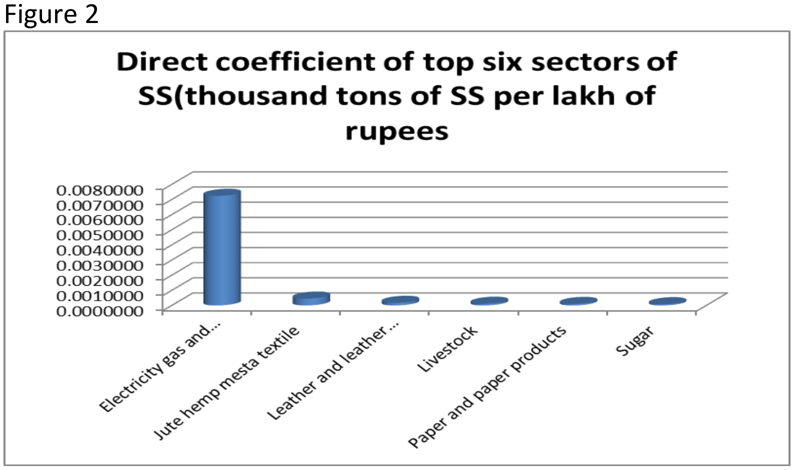


Figure 3 Direct coefficients of top six sectors of BOD (thousand tons of BOD per lakh of rupees)

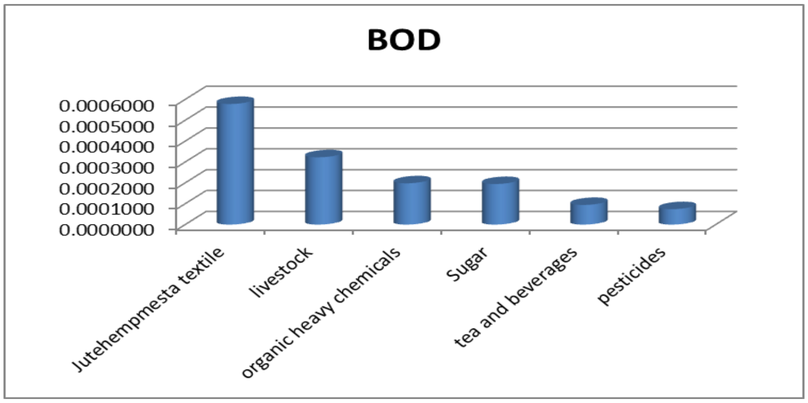
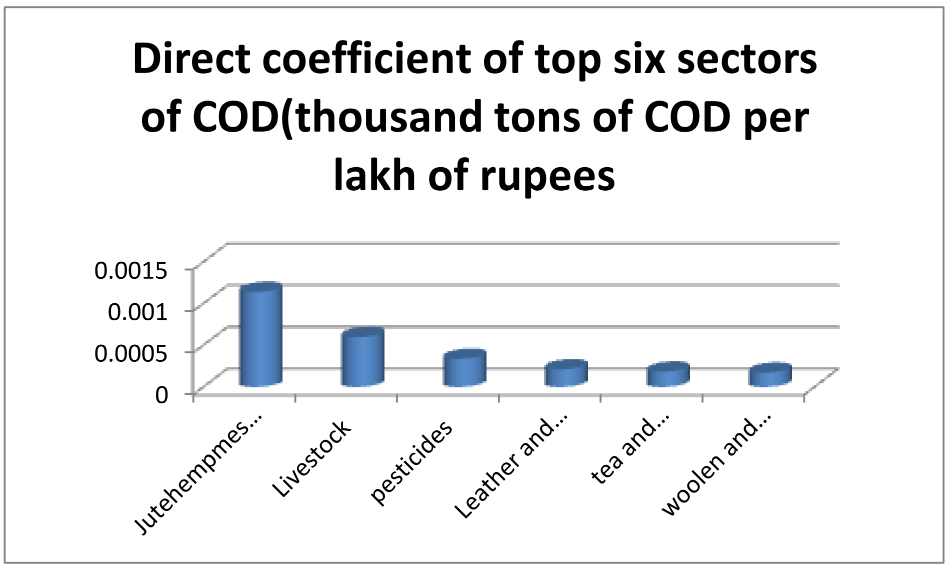


Figure 4



As we already mentioned that the contribution of total coefficients is observed for almost all the sectors even though the direct coefficients reveals zero. Figures 5 through 8 show top 8 sectors of total coefficient across four important pollutants- BOD, COD, SS and DS. The two common sectors like electricity and jute hemp mesta textiles are common in both direct and total coefficient list of SS. The new entries of textile, metallic sector, chemicals, tea and beverages are due to the indirect influence of the sectors. This is quite interesting in Input-output analysis and helpful for the policy makers. The total coefficient of sectors identified as top for the DS are almost common (other chemicals and miscellaneous textile products are also in the list) in direct coefficients.

Figure 5 Total coefficient of top 8 sectors of SS (thousand tons of SS per lakh of rupees)

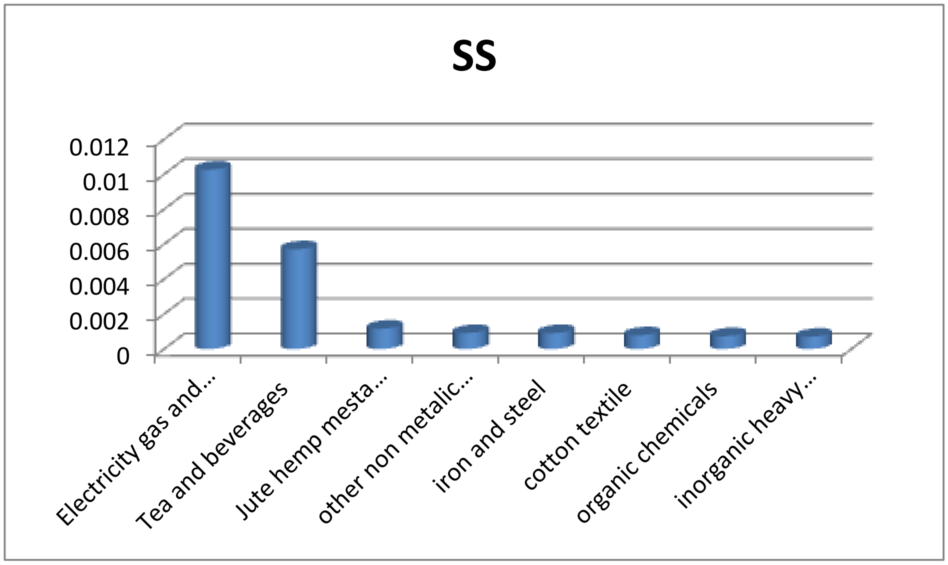
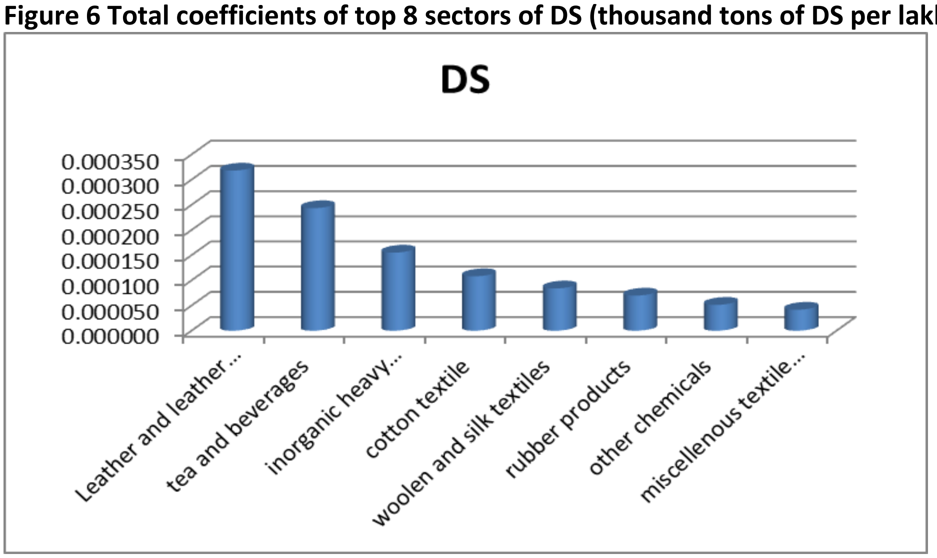


Figure 6 Total coefficients of top 8 sectors of DS (thousand tons of DS per lakh of rupees)



The sectors identified as top eight under BOD and COD is also having same features like DS. The sectors identified top in direct coefficient list is also present in total coefficient list except different types of textile products added in both cases.

Figure 7 Total coefficients of top 8 sectors of BOD (thousand tons of BOD per lakh of rupees)

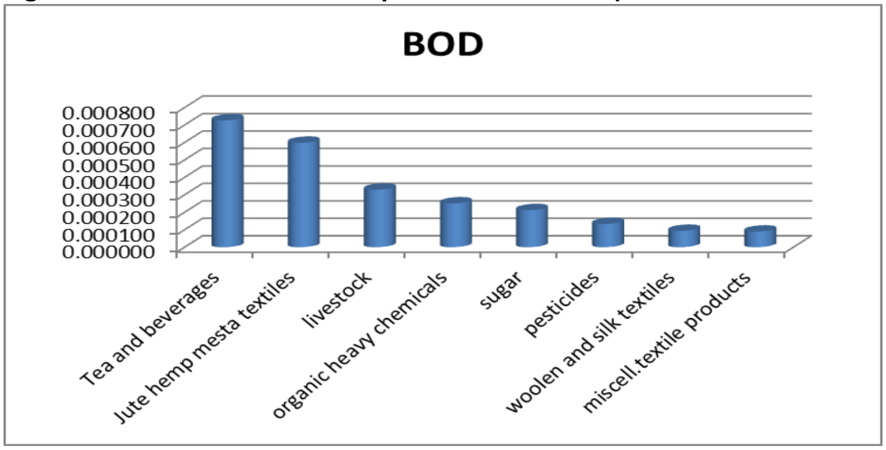
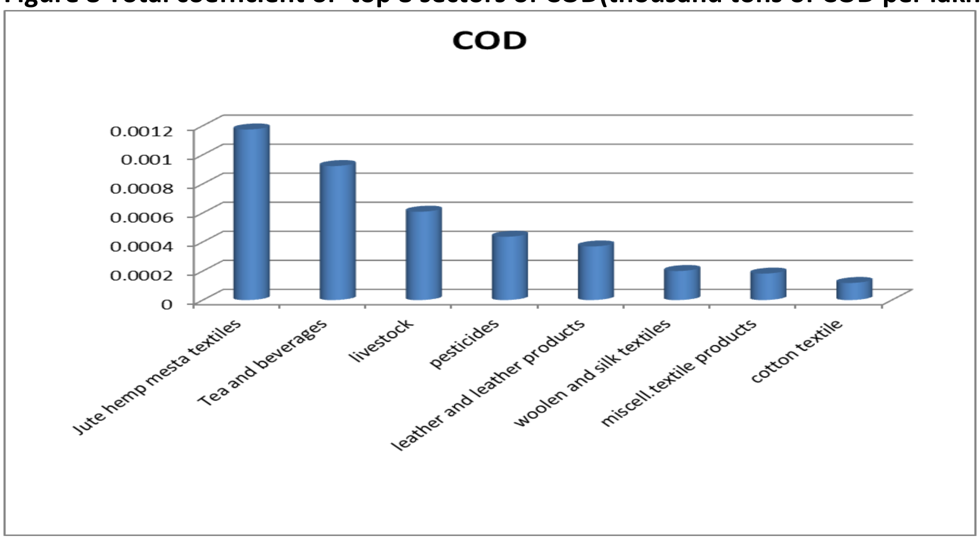


Figure 8 Total coefficient of top 8 sectors of COD(thousand tons of COD per lakh of rupees)



Total Amount of Pollution in Total Final Demand and Its Component

In this section we would find out the total amount of different types of pollution in total final demand and different components of final demand of different industries. In matrix notations the complete set of such multiplication can be described as follows

$\underline{R} = R^* \underline{Y}$

$\underline{R}$ is the amount of each one of the ten different kinds of pollutants (SS, DS, Chloride, Sulphide, Oil and Grease, Phenol, Zinc and Others, BOD and COD) generated directly and indirectly to meet total final demand of different sectors (10 x 38) of the year 2006-7.

R^* is the direct and indirect water pollution coefficient matrix of different sectors (10 X 38)

Y is the diagonal matrix of total final demand (38 X 38)

Table 3 shows the results of such computations. In this section matrices are transposed for the sake of conveniences. Rows of the table shows the total amount of different types of pollutant generated in the year 2006-7 by total final demand of different sectors. Some figures in table show negative entries as the total final demand of those particular industries are negative.

Examining the entries in final demand table, we see for example, that the additional output of SS generated to the delivery to final users of one additional Lakh Rupees worth of sugar product was responsible for the generation of 507 thousand tonnes of SS. Similar calculation has been done for each of the ten pollutants and other components of Final Demand (Private final Consumption Expenditure, Government Final Consumption Expenditure, Gross Fixed Capital Formation, Change in stock, Export and Import). Results of such computations are shown in table respectively.

Share of total amount of different types of water pollution in total final demand of all the sectors taken together and its components are shown in table. It appears form table that in that particular year 152373.49, 4142.571, 3009.516, 9965.18 and 16474.57 thousand tonnes of Suspended Solids, Dissolved Solids, Chloride, BOD and COD respectively are generated by total final demand of all the sectors. Here we captured the contributions made by private final consumption expenditure, export and import. Rest of the final demand sectors such as govt final consumption expenditure, investment and change in stock are not included. Highest contributions made by the private final consumption expenditure for all the pollutants.

Table 3 Total Amount of Different Water Pollution in Final Demand & its Component of India (For the Tear 2006-7) (Figures In '000 Tonnes per Lakh Rupees of Final Demand)

	SS	DS	CHLORIDE	SULPHIDE	OIL/GREASE	PHENOL	ZINC	OTHERS	BOD	COD
Final demand	152373.491	4142.571	3009.516	1276.989	1590.534	439.552	39.546	7771.363	9965.181	16474.572
Private final consumption expenditure	77588.909 (50.92)	2734.727 (66.02)	1639.276 (54.46)	697.335 (54.71)	1144.288 (71.94)	194.598 (44.27)	6.514 (16.47)	5460.228 (70.26)	6509.134 (65.32)	10650.313 (64.65)
Export	40720.83	1283.603	1167.744	474.667	521.516	556.443	5.797	1500.102	4147.828	4509.2489
Import	41510.9	987.645	429.871	167.752	605.577	846.13981	11.773	1037.561	4815.638	3602.716

(figures in the bracket are % share)

6. Conclusion

Almost all the countries of the world are becoming concerned with the environmental problems and environmental considerations are becoming a part of the overall development policy of every nation.

India, being a developing country, has to resolve massive environmental problems which include industrial pollution (i.e. pollution of air, water and soil due to industrial production), vehicular emissions, hospital waste and domestic sewage disposal, etc.

Industrial pollution in the form of air, water, solid, thermal pollution, etc., is assuming alarming proportions with each passing day and this category of problems needs immediate attention and calls for appropriate measures. The Indian industries have been producing pollution at much higher rates than the Minimal National Standard (MINAS) approved by the Pollution Control Board of India. An economy consists of a large number of industries. These industries do not exist in isolation from each other, rather, are interrelated. The interdependence arise from the fact that the output of a sector is generally required as input by another sector. Though some sectors do not produce pollution directly but these sectors produce pollution indirectly in a very significant way, depending on the methodology of interdependence among sectors of the economy under the framework of Input-output technique of Leontief. There have been several studies. But a quantitative analysis involving interdependence between water pollution and economic activities is only few (Maiti and Chakraborty 1999). With detailed and recent data an in-depth quantitative study linking the economy and water pollution by different sectors of the Indian economy has been done. The purpose of the present study is to contribute to this area. The present study has made detailed quantitative analyses of the link between water pollution generated by different industries and the various economic activities of the Indian economy for the year 1989-90. The study has computed the total amount of water pollution generation directly and indirectly in different industries of India using input-output technique. The input- output table (130 X130) of India for the year 2006-7 has been used and the table has been aggregated to 38 sectors. From the publications of the Central Pollution Control Board 10 types of water pollutant are identified which are being discharged by the different industries. However ,due to data limitation data for these 10 types (BOD,COD, Suspended Solids , Dissolved Solids , Chlorides, Sulphides, Oil & Grease, Zinc, Phenol and Others) of pollution have only available only for 30 sectors. The results show that the amount of total pollution generation per unit of the product is significantly higher for all industries compared to direct pollution generation coefficient. A significant numbers of industries in India are producing water pollution above MINAS by several times. Different types of Textiles either jute, hemp, mesta or cotton or woolen or miscellaneous is common and becoming top in list across the pollutants. Among other sectors leather products, paper products and chemicals is also deserved to be mentioned. The share of private final consumption expenditure is highest for almost all the pollutants among other final demand category. The export contribution is also high from the pollutants like COD, sulphide, chloride, DS and SS. It reflects that the generation of water pollution due to export activities is also high. The textile industry is vital to the Indian economy. The Indian textile industry is second only to agriculture in employment, providing jobs for over 35 million people. Textiles also represent more than 10 percent of the country’s exports. However, water pollution is causing a major damage. The World Bank estimates that 17 to 20 percent of industrial water pollution comes from textile dyeing and treatment. They’ve also identified 72 toxic chemicals in our water solely from textile dyeing, 30 of which are cannot be removed (Raybin, 2009).

Despite the clear signs of water scarcity, few Indian companies are accounting for their water risks. In a study released by Crisil Research, in a survey of 500 publicly traded companies they found that “only 30 percent of companies reported that they have company level water policy for prudent management of water usage. Similarly, 22 percent of companies reported that they have policies to manage waste water discharge.”

Indian government has already taking action against waste water released by the textile and dyeing units. Responsibility for water regulation and enforcement is up to the local states in India. This has resulted in “competition and conflict at all levels” according to the World Bank. But, there are signs of improvement and action, even if they’re uneven. Earlier this year, hundreds of dyeing units in Tirupur (south India) were closed by the state Pollution Control

Board due to excessive water pollution. Most of them remain closed until the area has established zero discharge processes, which are underway. In other states, in order avoid closure, various dyeing associations are scrambling to construct common effluent treatment plants (CETP) at a significant cost to the companies. But even the establishment of the CETP doesn't mean cleaner water. Poor planning led to at least one facility that didn't meet the guidelines set by the state Pollution Control Board (Bertelsen, 2011).

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