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The Costs of Water Pollution in India.

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1. Introduction

This report tries to summarize the information available about the different costs of water pollution in India. The variety of these costs comes not only from the variety of pollution dealt with (domestic, industrial, agricultural …) but also from the method used to calculate these costs.

The notion of cost is quite complex. Formally, it implies the comparison between two scenarios, and the assessment of the welfare of a group of economic agent in both scenarios. In the case of water pollution, the problem can be represented by a resource which provides environmental services, and economic agents that benefit from these services. Calculating a formal cost of water pollution would imply to model the different equilibrium at stake, and to deduct from these different equilibrium the effect of a difference in the ambient pollution on the aggregated welfare.

To determine these equilibriums, one would need hydrological as well as agronomic, medical and behavioural models that are not available as for now in India.

In practice, many different techniques are applied in order to provide estimates of the economic burden due to water pollution, that only provide partial estimates of a certain kind of cost, that is the cost of a particular aspect of pollution on a certain category of agents.

This document does not provide any original figure or data. It is a preliminary literature survey of the Indian context regarding water pollution. Although it aims at being as comprehensive and exhaustive as possible, many important elements might be missing, but we hope that reactions from the different partners will enable us to provide a reliable basis for common understanding and fruitful collaboration.

Political will, or financial resources are often quoted as critical element for a sound environmental policy, but information is surely at least as important as the other elements. Information on the status of environmental quality, on the sources of pollution, and the way it affects the different actors. This is the availability of such information, and the way it is being analysed and used in India that we tried to assess.

It appears that the availability of this kind of information has been enhanced by the effort of various institutions during the last fifteen years. The Central Pollution Control Board (CPCB), the Central Ground Water Board (CGWB), the Central Statistical Organisation (CSO) and several other institutions now provide nation wide data about water quality, industrial activity, etc…

We will first present the Indian regulation regarding water pollution. Current regulation can be defined as a command and control approach, based on emission concentration standards enforced by the different State Pollution Control Boards. We will then present the data available on pollution status for both surface and ground water. The main kind of pollution will be presented, i.e. pollution by domestic wastewater, pollution by industrial effluents, and pollution by agricultural run-offs. We will then give an overview of the studies that have attempted to cost water pollution. Several methods are represented in this survey, applied at different geographical levels. Finally, we present figures available on the major costs of pollution abatement.

2. Water pollution regulation in India

This sections gives an overview of the current state of the Indian environmental regulation system. We mention the main relevant texts regarding the regulation of water pollution. We then describe the main elements of the institutional set up, that is the pollution control boards, and the existing tools at their disposition. Finally we discuss the role of informal regulation by local communities.

2.1. Water pollution – related legislation

Unless there have been some environment related acts in India as early as the nineteenth century, the first significant laws regarding the protection of environmental resources appeared in the 1970's with the setting up of a National Comimittee on Environmental Planning and Coordination, and the enactment of the Wildlife Protection Act, 1972.
Since then, three main texts have been passed at the central level, that are relevant to water pollution : the Water (Prevention and Control of Pollution) Act, 1974, the Water (Prevention and Control of Pollution) Cess Act, 1977 and the Environment (Protection) Act (1986).

The Water Act 1974 established the Pollution Control Boards at the central and state level.
The Water Cess Act 1977 provided the Pollution Control Boards with a funding tool, enabling them to charge the water user with a cess designed as a financial support for the board's activities.
The Environment Protection Act 1986 is an umbrella legislation providing a single focus in the country for the protection of environment and seeks to plug the loopholes of earlier legislation relating to environment.
The law prohibits the pollution of water bodies and requires any potentially polluting activity to get the consent of the local SPCB before being started.

2.2. Institutional set-up The pollution control boards

Composition : Each board is composed of a chairman and five members, with agriculture fisheries, and government-owned industries having representation.

2.2.1. The Central Pollution Control Board (CPCB)

The CPCB has overshight powers over the various state boards. It sets emission standards, and lays down ambient standards. The CPCB also conducts nation wide surveys about the status of pollution, and of pollution mitigation.
Two programs of inland water quality monitoring have been set up so far, leading to the spreading of 480 measurement stations over the main river basins of the country. These two programs are the Global Environment Monitoring System (GEMS) and Monitoring of Indian Aquatic Resources (MINARS). The ganga river is subject to a dedicated program called Ganga Action Plan (GAP) under which a water quality control network as been set up in the ganga basin. The measurement are made in different kind of medium (river, wells, lakes, creeks, ponds, tanks, drains and canals) and 25 physico-chemical and biological parameters are monitored.

2.2.2. The State Pollution Control Boards (SPCB)

The implementation of the national environmental laws, and the enforcement of the standards set by the CPCB is decentralised at the level of each state, with the SPCB in charge of this role. The SPCB can demand information from any industry about the compliance with the Act. Non-compliance can be punished with fines up to Rs. 10000, and imprisonment up to three months. In case of continued non-compliance, an additional daily fine of 5000 Rs. can be imposed. Until 1988, the only enforcement tool of the SPCB was criminal prosecution. This was revised by the 1988 amendment to the Water Act of 1974. The boards now have the power to close non-compliant companies or to cut their water and power supply. The ultimate recourse remains public interest litigation in front on the supreme court. During the last decade, the supreme court has been involved several times in large scale environment related measures. In April 1995 for example, the Supreme Court of India, in a public interest litigation case, has ordered that 538 tanneries located in 3 clusters in Calcutta generating about 30 mld of effluents be shifted from the city to a leather complex and a CETP (Common Effluent Treatment Plant)be provided to treat the effluent generated from the complex. In 1996, it has ordered the closure of all tanneries in Tamil Nadu that had not set up pollution control systems.

However, control and sanction is not the only way of interaction between the boards and the polluting entities. Under the Water Cess Act of 1977 state boards may charge industries and municipalities with a water cess calculated on the volume of water consumed, and for consent fees. Nevertheless any fee levied by the SPCBs have to be sent to the central government. The central government is then supposed to return 80% of the fees to the SPCBs

2.2.3. Assessment of the action of SPCBs.

In 1996, a survey of India's pollution regulatory structure was conducted by the world bank (Shaman 1996). It shows that SPCBs have suffered from a lack of efficiency during their formative years. One plausible cause for this inefficiency might be the low rate of return of the funds sent by the SPCBs to the central government. By 1987-88, all the state boards had filed a total of only 1,602 cases for prosecution under the Water Act. Of these, 288 had been decided and 1,314 cases were still pending. Recent signs indicate more vigilance by government officials toward violators.

In 1991, the CPCB Board began implementation of an coordinated action plan for industrial pollution control with the state boards. The Board selected 17 highly polluting manufacturing sectors. In addition to identifying critical manufacturing sectors, the Board went on to determine which geographical locations had been most affected by industrial pollution. It identified 13 extremely polluted waterways. Following consultations with the state boards, 22 critically polluted areas around the country were also identified. All these sites and rivers were targeted for short-term emergency programs.

The Board also sought to identify polluters by size. Again working with their state counterparts, the Board also identified 1,551 large and medium sized units throughout India. 1,125 were found to be in compliance. 319 plants were found to be not in compliance. Of those 319 plants, 258 had begun operating before 1981. The remaining 107 plants were ultimately closed.

In 1994, Indian courts closed almost 1,000 factories for pollution problems. In addition, the Supreme Court fined 15 plants, including some multi-nationals. (Source : Shaman, 1996)

In 1997, another team of economists from the world bank (Pargal, Mani & Huq, 1997) looked for evidences of influence of inspections from the SPCBs on emission by polluting firms. The results, however, showed only a higher level of inspection in highly polluted areas, but no causal links between the level of inspection and a decrease in emissions. The study did not find neither evidence of informal pressure from local population on polluting industries.

2.3. Regulatory tools

2.3.1. Environmental standards

2.3.1.1. Ambient standards for river quality

Table 1 Primary Water Quality Standards

	Designated best use				
Criterion	Class A	Class B	Class C	Class D	Class E
Dissolved Oxygen (mg/l) Maximum	6	5	4	4	-
BOD (mg/l) Maximum	2	3	3	-	-
Total coliform count (MPN/100 ml) Maximum	50	500	5000	-	-
pH acceptable range	6.5-8.5	6.5-8.5	09-juin	6.5-8.5	6.5-8.5
Free ammonia (mg/l)	-	-	-	1.2	
Condustivity	-	-	-	-	2.25
Sodium absorbtion ratio	-	-	-	-	26
Boron (mg/l)	-	-	-	-	2

Class A: Drinking water source without conventional treatment. Class B: Water for outdoor bathing.
Class C:Drinking water with conventional treatment. Class D: Water for wildlife and fisheries
Classe E: Water for recreation and aesthetics, irrigation and industrial cooling.

Source : CPCB

2.3.1.2. Discharge standards: MINAS

The CPCB has issued a set of norms that have to be enforced by the SPCBs. Those standards are expressed in terms of effluent concentration and are called Minimum Acceptable Standards (MINAS). SPCB have the choice to adopt more stringent standards.
The MINAS are defined for each type of industry and for each type of medium of release. Classical criteria are BOD, COD, and TSS.
The MINAS standards concerning those criteria are respectively of 30 mg/L, 250 mg/L, and 100 mg/L.

2.3.2. The water cess

Table 2 Industries Subject to Water Cess

1. Ferrous metallurgical industry
2. Non-ferrous metallurgical industry
3. Mining industry
4. Ore processing industry
5. Petroleum industry
6. Petrochemical industry
7. Chemical indsutry

8. Ceramic indsutry
9. Cement industry
10. Textile industry
11. Paper industry
12. Fertiliser industry
13. Coal (including coke) industry
14. Power (thermal and disesel) generating industry
15. Processing of animal or vegetable products industry

Source : The water (Prevention and Control of Pollution) Cess Act, 1977

Table 3 Rate of Water Cess

Purpose for which water is consumed	Maximum rate (Paisa per kilolitre)	Maximum rate (Paisa per kilolitre) in case of non-compliance of the water user with the environmental standards
Industrial cooling, spraying in mine pits or boiler feeds	1.50	2.25
Domestic purpose	2.00	3.00
Processing whereby water gets polluted and the pollutants are easily biodegradable and are toxic.	4.00	7.50
Processing whereby water gets polluted and the pollutants are not easily biodegradable and are toxic.	5.00	7.00.

Source : The water (Prevention and Control of Pollution) Cess Act, 1977

2.3.3. Other economic incentives

- Depreciation allowance: A depreciation of 100% per cent is provided on specific equipment installed by manufacturing units to control pollution.
- Water cess: If an industry has installed equipment for treatment of sewage or effluent, it can avail of a rebate of 70 per cent on the water cess, which is levied on water use.
- Concessional custom duty: Equipment and spares for pollution control attract reduced rates of customs duty
- Excise duty: Excise duty at reduced rate of 5% on manufactured goods that are used for pollution control
- Soft loans: Financial institutions can extend soft loan facilities for installation of pollution control equipment
- Subsidies: Small scale industries can receive financial assistance and subsidies to set up common effluent treatment facilities

2.4. Special schemes

2.4.1. The Common Effluent Treatment Plants Schemes

Pollution from small size industries (SSIs) puts the Indian regulators in front of a difficult arbitrage between economic development and environmental sustainability. Indeed, 40% of the wastewater generated by Indian most polluting industries comes from small size industries. With the adoption of the water act, those small size industries had in theory the obligation to treat their effluent in order to reach a pollution concentration respecting the minimum acceptable standards laid down by the SPCBs. Nevertheless, the size of these facilities makes the installation of a standard effluent treatment plant (ETP) unaffordable because of the important fixed cost of an individual ETP. Therefore, public authorities have taken the initiative to promote common effluent treatment plants (CETPs) schemes, allowing small industries to gather in order to treat jointly their effluents. The CETP concept was originally promoted by the Ministry of Environment and Forests in 1984. The first CETP in India was constructed in 1985 in Jeedimetlha near Hyderabad, Andhra Pradesh, to treat waste waters from pharmaceuticals and chemicals industries. In 1999, 82 CETPs had been set up around the country.

Although CETPs are mainly seen as a mean to take advantage of scale economies, these schemes also act as subsidies from public powers to small industries in order to allow them to respect the standards.

The minimum participation asked from SSIs in the CETP schemes implemented in India is 20%. The rest is funded through subsidies from central and state governments as well as loans from international organisations such as the world bank or Indian institutions such as IDBI or ILFS.

The subsidy effect in favour of SSIs may be increased in some cases when an industrial area gathers SSIs as well as larger polluting industries. In these case, some cross subsidies may be set up by asking the larger industries to contribute to the development of the CETP while treating their effluent before releasing them in the common drain.

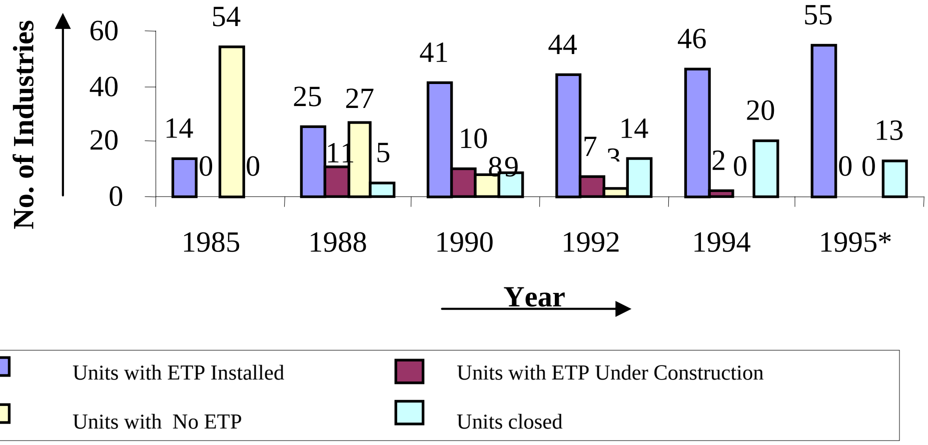
There are in fact diverging opinions on the relevance of CETPs in a national pollution abatement policy. It has been clearly shown that compared to individual ETPs, CETPS are more cost effective in reaching the effluent concentration standards. (Pandey & Deb, 1998; Sankar 1998). However, treating the effluents is not the only way to meet the standards, and process changes induced by regulatory pressure have proved to give good results in several results, and can even enhance the company's competitiveness. In a seminal article published in 1991, Michael Porter formulated what is usually referred to as the "Porter Hypothesis" : "Strict environmental regulations do not inevitably hinder competitive advantage against foreign rivals; indeed, they often enhance it" (Porter, 1991). A test of the Porter hypothesis on the Indian manufacturing industry was recently carried out by Murty and Kumar (Murty & Kumar 2001) Taking this element into account, one can wonder if the CETPs are really a viable long term solution , or if they simply delay a necessary effort of process adaptation from the concerned industries.

2.4.2. The River action plans

The National River Conservation Directorate (NRCD), under the Ministry of Environment and Forest, Government of India, is in charge of coordinating several river conservation plans. Those plans basically consist in the setting up of sewage diversion and treatment facilities, along with action directed toward mitigation of industrial pollution through the seting up of Individual or Common Effluent Treatment Plants (ETPs)

The first large scale action plan oriented towards conservation and rehabilitation of water resources was the Ganga Action Plan (GAP), launched in 1985. The Ganga River Basin is one of the most populous in the world with 5 Indian states relying on the Ganga for their water needs (Haryana, Delhi, Uthar Pradesh and West Bengal). The river system has been divided in several streches for which objectives of water quality were fixed using the primary water quality standards defined in table 1. The main elements of the strategy adopted for the first phase of the Ganga Action Plan were a combination of diversion and treatment of sewage from the major cities in the river basin, as well as provision of low cost sanitation for rural areas, and other interventions such as river banks development and setting up of electric crematorium. In practice, only the first part of the plan consisting in diversion of sewages has been fully implemented. Out of the 1340 MLD capacity that was initially targeted for sewage treatment, only 873 was actually set up.
The GAP has however led to an observable enhancement of river quality in the Ganga.
Along with the actions directed toward domestic pollution, 68 highly polluting were identified along the Ganga River Basin and were asked to conform with the standards by setting up ETPs.

Chart 1. Yearwise Progress of ETP Installation in the 68 Industries concerned by the GAP



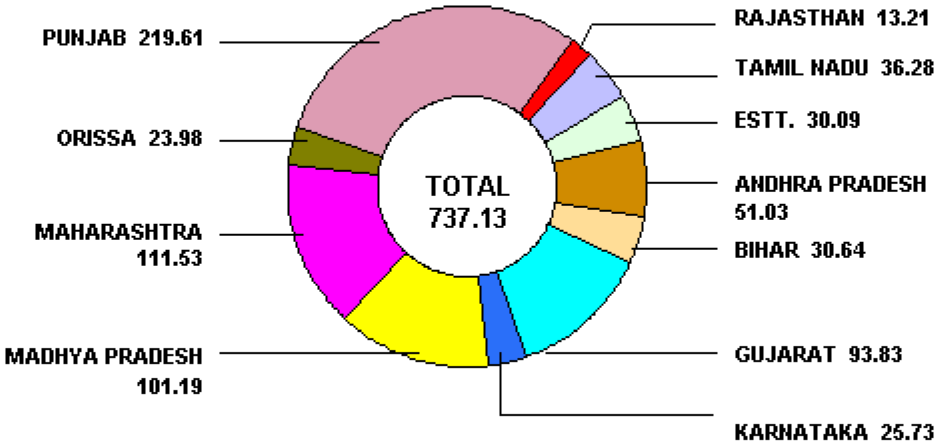
Source : CPCP

A comprehensive Cost-Benefit Analysis of the Ganga Action Plan was published in 2000 (Markandya & Murty 2000)
The First phase of the Ganga Action Plan has led to other sub-action plans : the Yamuna, Gomati, and Damodar Action Plans, as well as the second phase of the GAP.

The National River Conservation Plan (NRCP) was launched in 1995 to cover 18 major rivers in 10 states of the country. Under this action plan pollution abatement works are being taken up in 46 towns in the states of A.P., Bihar, Gujarat, Karnataka, Maharashtra, M.P., Orissa, Punjab, Rajasthan and Tamil Nadu. About 1928 mld of sewage is targetted to be intercepted, diverted and treated.
The total NRCP sanctioned cost is of Rs. 737.13 Crore.

The following chart give a repartition of this cost by state.

Chart 2. State-Wise sanctioned cost of National River Conservation Plan



Source : NRCP

The following table summarizes the the scheduled scope and cost of the different plans implemented.

Table 4 Programs implemented by the National River Conservation Directorate

Name	Number of towns covered	Volume of Sewage Diverted / Treated (MLD)	Cost (Rs. Crores)
Ganga Action Plan Phase I	25	873	462.04
National River Conservation Plan	46	1928	737.13
Yamuna Action Plan	20	744	823.57
Gomati Action Plan	3	269	61.11
Damodar Action Plan	12	68	23.58
Ganga Action Plan Phase II (main stem)	29	618	378
Ganga Action Plan Phase II (Supreme Court Towns)	30	162	209.90

Source : NRCD

2.4.3. The National Drinking Water Mission

The Accelerated Rural Water Supply Programme (ARWSP) was introduced in 1972-73 by the Government of India to assist the States and Union Territories (UTs) to accelerate the pace of coverage of drinking water supply. The entire programme was given a Mission approach with the launch of the Technology Mission of Drinking Water and Related Water Management, also called the National Drinking Water Mission (NDWM), in 1986. It was one of the five Societal Missions launched by the Government of India. The NDWM was renamed as the Rajiv Gandhi National Drinking Water Mission (RGNDWM) in 1991.

In addition of the ARWSP, the government launched a similar initiative on sanitation. The centrally Sponsored Rural Sanitation Programme (CRSP) was laun ched in 1986 .

2.5. Community action and informal regulation

In addition to the action of the different administrative agencies, some kind of pollution regulation can be enforced by direct action of affected communities. According to Goldar and Banerjee (2002) the two channels of informal regulation are (1) to report violation of legal standards to the regulatory institutions (where such standards and institutions exist), and (2) to put pressure on regulators (politicians and administrators) to tighten their monitoring and enforcement.

Pargal, Mani and Huq (1997), and Murty and Prashad (1999) have carried out field survey of effluent discharge from small and medium industries in order to study how the characteristics of local communities impact on the environmental behaviour of local industries. Goldar and Banerjee (2002) have performed a similar study taking environmental water quality instead of industries's effluent discharge as a measure of the output of informal regulation.

3. Pollution Status

3.1. Surface water pollution

As mentioned in section 2, the CPCB has set up several network or river quality monitoring stations. In 1999, there wer 507 such stations, of which 430 were set up under the Monitoring of Indian National Aquatic Resources (MINARS) program, 50 stations under Global Environmental Monitoring Systems (GEMS), and 27 stations under the Yamuna Action Plan (YAP).

The water quality was compared with desirable water quality expressed in terms of the quality class defined in table 1 following the best use of water.

Table 4 shows some of the most polluted river stretches. The level of unwanted pollution is given by the difference between the desired class and the existing class. Table 4 also proposes some explanation for the pollution observed. It can be seen that the major sources of pollution identified are domestic pollution from large cities, an industrial pollution from industries such as sugar industry, distilleries, tanneries, or fertilisers.

Table 5 List of polluted river stretches

River	*Polluted stretch*	*Desired class*	*Existing class*	*Critical parameters[a]*	*Possible source of pollution*
Sabarmati	Immediate upstream of Ahmedabad up to Sabarmati Ashram	B	E	DO, BOD, Coliform	Domestic and industrial waste from Ahmedabad
	Sabarmati Ashram to Vautha	D	E	DO, BOD, Coliform	Domestic and industrial waste from Ahmedabad
Subarnarekha	Hatia dam to Bharagora	C	D/E	-do-	Domestic and industrial waste from Ranchi and Jamshedpur
Godavari	Downstream of Nasik and Nanded	C	D/E	BOD	Wastes from sugar industries, distilleries and food processing industries
Krishna	Karad to Sangli	C	D/E	BOD	Wastes from sugar industries and distilleries
Sutlej	Downstream of Ludhiana to Haike	C	D/E	DO, BOD	Industrial wastes from hosieries, tanneries, electro-plating and engineering industries and domestic waste from Ludhiana and Jalandhar
	Downstream of Nangal	C	D/E	Ammonia	Wastes from fertiliser and chloralkali mills from Nangal
Yamuna	Delhi to confluence with Chambal	C	D/E	DO, BOD, Coliform	Domestic and industrial wastes from Delhi, Mathura and Agra
	In the city limits of Delhi, Mathura and Agra	B	D/E	DO, BOD, Coliform	Domestic and industrial wastes from Delhi, Mathura and Agra
Hindon	Saharanpur to confluence with Yamuna	C	D	DO, BOD, Toxicity	Industrial and domestic wastes from Saharanpur and Ghaziabad
Chambal	Downstream of Nagda and downstream of Kota	C	D/E	BOD, DO	Domestic and industrial waste from Nagda and Kota
Damodar	Downstream of Dhanbad	C	D/E	BOD, Toxicity	Industrial wastes from Dhanbad, Durgapur, Asansol, Haldia and Burnpur
Gomti	Lucknow to confluence with Ganges	C	D/E	DO, BOD, Coliform	Industrial wastes from distilleries and domestic wastes from Lucknow
Kali	Downstream of Modinagar to confluence with Ganges	C	D/E	BOD, Coliform	Industrial and domestic wastes from Modinagar

Source : CPCB 1999 (reported in MoEF 2001)

Table 5 gives pollution level for the different Indian states. The criteria presented are Biological Oygen Demand, Total Coliform, and Faecal Coliform. While BOD excess can be the result of both domestic or industrial pollution, Coliform count is directly related to domestic wastewater.

Table 6 Water Quality Status in India

	BOD (mg/l)			*Total Coliform* (MPN/100 ml)			*Faecal Coliform* (MPN/100 ml)		
State	*< 3*	*3-6*	*>6*	*<500*	*500-5000*	*> 5000*	*< 500*	*500-5000*	*> 5000*
Andhra Pradesh	202	56	19	16	25	0	37	0	0
Assam	113	4	9	15	49	23	22	21	0
Bihar	146	3	1	15	48	82	35	106	2
Daman & Diu	28	0	0	11	13	0	12	9	0
D & N Haveli	16	0	0	3	11	0	6	7	0
Delhi	11	4	14	0	6	14	10	5	5
Gujarat	224	82	125	200	63	164	214	90	116
Goa	33	15	0	48	0	0	44	0	0
Himachal Pradesh	88	1	0	61	27	1	83	6	0
Haryana	28	4	9	0	0	0	0	0	0
Karnataka	247	49	52	94	283	0	113	136	1
Kerala	275	1	0	10	238	24	71	192	12
Lakshdweep	6	2	0	3	5	0	6	2	0
Maharashtra	0	326	123	375	73	0	391	0	0
Manipur	30	2	0	27	5	0	0	0	0
Meghalaya	0	4	16	12	6	2	9	8	0
Madhya Pradesh	345	114	48	373	124	0	209	0	0
Orissa	22	298	57	234	143	0	299	78	0
Punjab	26	26	20	72	0	0	71	1	0
Pondicherry	15	1	3	0	0	0	0	0	0
Rajasthan	71	5	2	36	42	0	78	0	0
Tamil Nadu	260	38	6	168	72	63	219	53	31
Tripura	30	1	1	4	17	0	18	3	0
Uttar Pradesh	210	165	176	29	123	161	114	123	49
West Bengal	110	24	0	89	0	0	89	0	0
Total	2536	1225	681	1895	1373	534	2150	840	216

Source : CPCP 1999 (reported in MoEF 2001)

3.2. Groundwater Quality problems in India.

In this section, we will deal only with quality-related problems of ground water in India, putting aside the problems of lowering of the water table due to over-exploitation. Nevertheless, we will study a broader problem than the one of pollution per say, dealing with water quality problem that can be considered as not being pollution-related, since most of them are mainly geogenic.
Indeed the main quality problem encountered with ground water in India are due to excess fluoride, arsenic, iron, nitrate and salinity. Nitrate contamination is mainly anthropogenic, due to the use of fertilizers and discharge of fecal material. Salinity may have different origin, but the most common is the infiltration of brackish water in a fresh aquifer due to the over exploitation of this aquifer.

3.2.1. Ground water use

It is estimated that 80% of domestic needs in rural areas and 50% in urban areas is met by ground water.[1]

India's total replenishable groundwater have been estimated at 431.8 km^3 by the Central Statistical Organisation. The average level of groundwater development in India is 32%, although some states have exploited their resources to a much greater extent (94% in Punjab, 84% in Haryana, 60% in Tamil Nadu, 64% in Lakshadweep, 51% in Rajasthan)[2].

85% of ground water extracted is used for irrigation purposes and 15% for Industrial and domestic. purposes.[3] Reciprocally, as much as 70 to 80% of India's agricultural output may be groundwater dependent.

3.2.2. Quality problems

3.2.2.1. Quality problems in rural areas.

A survey carried out by the Rajiv Gandhi National Drinking Water Mission, GoI, based on 1% random sampling indicated that 217211 habitations had water quality problems.

Table 7 Number of Habitations affected with Water Quality Problems

Nature of Quality Problem	Number of affected habitations
Excess Fluoride	36988
Excess Arsenic	3553
Excess Salinity	32597
Excess Iron	138670
Excess Nitrate	4003
Other reasons	1400
Total	217211

[1] India tenth plan. 8.1.54

[2] Central Statistical Organisation (1997) "Compendium of Environmant Statistics". New Delhi: Department of Statistics, Ministry of Planning and Programme implementation, Government of India.

[3] Ramesh Chandra Panda, Mission Director, Rajiv Gandhi National "Drinking Water Mission. Drinking Water Quality and Related Health Impact in Rural India" Presented in the 3rd World Water Forum, Kyoto, 2003.

3.2.3. Fluoride:

High fluoride concentration in ground water beyond the permissible limit of 1.5 p.p.m is one of the most worrying toxicological problems India. This contamination has geological origins, and dangerous level of Fluoride presence in ground water have been recorded in 17 different states, covering almost the hole territory. In affected areas, the range of fluoride contamination varies between 1.5 and 29 p.p.m. Prolonged ingestion of high quantities of fluoride can lead to dental or skeletal fluorosis.

According to a survey carried out by the Rajiv Gandhi National Drinking Water Mission (RGNDWM) in 1993, around 25 million people were affected at this time. The population at risk is estimated at 66 million

3.2.3.1. Origin

The fluoride is present in many different geological formations, but the gneiss of the Indian underground have been identified as being responsible for the problematic fluoride concentration in ground water.

3.2.3.2. Fluoride mitigation

Department of Drinking Water Supply of the Ministry of Rural Areas and Employment, Government of India, has constituted a Central Task Force to facilitate in setting up of a Centre of Excellence for Fluorosis Mitigation.

A sub mission of the RGNDWM has been created for the control of fluorosis. Control measures include the installation of fluor removal plants using processes based on Nalgonda technique or activated alumina process. Those plants can be either fill and draw or handpump-attached). 499 such plants had been approved in 1998, of which 1998 had been installed upto December 1998.

The main methods identified for Fluoride removal are
Co-precipitaion
Adsorption by activated carbon and activated alumina
Exchange method
Reverse Osmosis

3.2.4. Arsenic:

Arsenic contamination of groundwater has an unusually high and dramatic occurrence in the gangetic delta including West Bengal and Bangladesh. The first indication of arsenic-related health problems was reported in West Bengal in 1983. It took ten more years for the situation to be recognised in Bangladesh. Since then, several programs of investigation have been carried out and the arsenic crisis in the ganga delta is now the focus of many efforts worldwide to release the population living in this area from this serious threat. Arsenic contamination through drinking water may be responsible for cancer of skin, lungs, urinary bladder, and kidney, as well as other skin affectations. The population at risk is estimated at 5.3 million, with 200000 people actually affected.

3.2.4.1. Origin

Arsenic is widespread in the earth's crust. The concentration of arsenic, however, is particularly high in the thick succession of fluviatile sediments pertaining to the quaternary age that form the majority of the exploited aquifers in the region.

Although everyone agrees about the geologic origin of the arsenic that can be found in ground water in West Bengal and Bangladesh, there is no consensus about the reason why the arsenic gets diluted at such a high rate.

Some scientist assume that the high arsenic concentration in groundwater can be explained by the exposition of arseno-ferous complex to atmospheric oxygen introduced in the aquifer in response to lowering of groundwater level.
An alternative explanation puts forward the strongly reducing condition of the aquifer, that can be explained by the burial of organic sediment during its geological formation.
This two - mostly geogenic - explanations are challenged by another one based on the action of phosphates from chemical fertilizers that could displace arsenic from the sediment.

3.2.4.2. Contamination

Arsenic in drinking water.
WHO standards concerning Arsenic concentration in drinking water established in 1993 an allowable concentration of 0.01mg/L, bringing down the 1963 limit of 0.05mg/L. However, the permissible limit in India and Bangladesh, is still 0.05 mg/L, and most of the test done in those areas use this reference.
Nine of sixteen districts of West Bengal have been reported to have ground water arsenic concentrations above 0.05mg/L[4]. According to the Public Health Engineering Department (PHED) in Calcutta, the population of those nine districts is estimated at 39 million. There are around 22000 public tubewells and more than 400000 private tubewells in the area. In the tenth five-year plan document prepared by the Indian Planning Commission, it was reported that arsenic contaminated habitations had been identified in eight districts, with 200,000 people actually affected, and an exposed population around 5.3 million. The reported number of tubewells in the affected area was 22000 public tubewells, and 130000 private tubewells. These figures, compared to the one provided by the PHED, show the lack of information about the private tubewells, which is a major obstacle in the efforts to assess the real extent of the crisis.

Arsenic in biomass.
The problem of arsenic in drinking water is maybe the more urgent to be solved, but finding solutions for providing safe drinking water will not prevent totally As ingestion as long as As enters the surface environment through extracted ground water. Animals drinking contaminated water may accumulate As in their tissues, as well as crops grown in a field irrigated with As contaminated groundwater. Irrigation poses an even more serious threat to the environment, through a potential long term contamination of soils, and maybe a subsequent contamination of surface water flows.
Until recently, no study was conducted to explore those alternative pathways. The Indian Council of Agricultural Research as started a study in 1998 about the impact of As contamination in terms of agricultural management.[5]
Although the surface water was not found to be heavily contaminated, the study showed that As tends to accumulate in most of the crop cultivated on the soils irrigated with contaminated water. Moreover, the As present in the crops is mostly in its most toxical form of arsenate.

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[4] Chowdhury U.K., Biswas B.K., Chowdhury T. Roy, Samanta G., Mandal B.K., Basu G.K., Chanda C.R., Lodh D., Saha K.C., Mukherjee S.C., Roy S., Kabir S, Ouamruzzaman Q., Chakraborti D. (2000) "Groundwater Arsenic Contamination in Bangladesh and West Bengal, India" Environmental Health Perspectives Volume 108, Number 5, May 2000
[5] ICAR (2001) "Final Report: Status, causes and impacts of arsenic contamination in groundwater in parts of West Bengal vis-avis management of agricultural systems." *Ad-hoc* Scheme executed by BCKV; NBSS & LUP, NDRI, GSO, CSSRI, SWID. Principal Investigator – Sanyal, S.K.

3.2.4.3. Arsenic mitigation in West Bengal

Mitigation strategies

Arsenic contamination can be avoided either by providing an arsenic-free water supply, either by providing an arsenic removal technology.

- Providing an arsenic-free water supply, can be achieved by :
  - Using surface water.
  - Rainwater harvesting
  - Tapping into deeper aquifers (100-150 meters), or shallow aquifers (hand-dug wells less deep than 20 meters) which have been found to be arsenic free.
- Providing an arsenic removal technology which can be used, either at the level of the household, either at a more central level. There is now eight main classes of arsenic remediation technologies based on the following processes : 1. Oxidation, 2. Coagulation/Co-precipitation, 3. Sedimentation, 4. Filtration, 5. Adsorption, 6. Ion Exchange, 7. Membrane/Reverse Osmosis, 8. Biological.[6]

The Water and Sanitation Program (WSP) has conducted a field study about the technologies being tested in West Bengal and Bangladesh for Arsenic Mitigation. Seven promising technologies were identified.

- Two bucket Treatment Unit : this rustic technology is based
- Three Kalshi Filter Unit
- RKM Filter Unit
- Amal Domestic Water Purifier
- Passive Sedimentation
- Co-precipitation Using Tablet Reagents
- Adsorption

3.2.5. Iron:

High concentration of Iron in drinking water is the most widespread quality problem in India. Nevertheless, the health impact of this contamination is smaller than the one caused by arsenic of fluoride contamination. Using Iron contaminated water, that is over the permissible limit of 1 ppm can cause constipation accompanied by other physiological disorders.

The RGNDWM sub mission dedicated to the removal of Excess Iron had approved 1615 and 9355 plants had already been commissioned in 1998.

3.2.6. Brackishness:

Brackishness may be an initial characteristic of some aquifers, but it can be caused or worsened by infiltration due to overexploitation of the aquifer. This is often the case in coastal areas where aquifers get contaminated with infiltrated sea water.

Excess brackishness in drinking water has laxative effects.

The permissible limit is set at 1500 ppm of total dissolved solids (TDS).

194 desalination plants have been approved by the RGDWM and 150 plants had been commissioned up to 1998.

[6] Susan E. Murcott "Arsenic Remediation Technologies Online Informational Database" MIT http://web.mit.edu/murcott/www/arsenic

4. Sources of Human Pollution

4.1. Pollution by domestic wastewater

In the tenth plan document from the Indian planning commission sewage alone was reported to be responsible for 80% of the total water pollution in the country.

4.1.1. Domestic pollution in urban environment

Theoretically, the Indian cities and towns are accountable for their wastewater discharge. Therefore, they are supposed to collect and treat all their wastewater. They are also supposed to pay a water cess proportional to their water consumption to the local State Pollution Control Board (SPCB). In practice however, these rules are not applied. As it is illustrated by the CPCB statistics presented hereunder, even the class I cities, (the largest Indian cities) are treating a small part of their effluents, while the smaller towns practically don't have any treatment facilities.
The SPCB do not feel they have enough authority to impose some pressure on the municipalities to have them comply with the regulation.
In such a situation, the incentive for the municipal bodies to enhance the collection and treatment of wastewater comes from the local demand for better quality.

Status of wastewater generation, collection and treatment in class I cities and class II towns (MLD)

Type	Number of Cities/Towns	*wastewater generated* (MLD)	wastewater collected		wastewater treated		
			MLD	% (of generated)	MLD	% (of collected)	% (of total)
Class I cities	299	16662.5	11938.2	72	4037.2	33.8	24
Class II towns	345	1649.6	1090.3	66	61.5	5.6	3.7
Total	644	18312.1	13028.5	71	4098.7	31.5	22.4

Source CPCB 2000

4.1.2. Domestic pollution in rural environment

No figures are available about the non point source pollution due to domestic wastewater discharge in rural areas.
According to the Central Statistical Organisation (CSO), 3.15 % of the rural population had access to sanitation services in 1993. This left around 563.6 million people living in rural areas had no access to toilets.
Global numbers about this kind of pollution would not be very useful anyway, since the effect of such a pollution is essentially local, and intimately linked with the local practice of water fetching and hygiene.

4.2. Pollution by Industrial effluents

Major polluting industries

The CPCB has laid down a list of major polluting industries in 1989. Those industries are subject to a special regime of inspection from the SPCBs and are subject to the water Cess.

Those industries are :
1. Cement mills (above 200t/ day)
2. Sugar
3. Thermal Power plants
4. Distilleries
5. Fertilizers
6. Oil refineries
7. Caustic Soda Production
8. Petrochemicals
9. Zinc Smelting
10. Copper Smelting
11. Aluminum Smelting
12. Sulphuric acid
13. Integrated Iron and Steel
14. Pulp and Paper
15. Tanneries
16. Pharmaceuticals
17. Dye and Dye Intermediates
18. Pesticides

Source : CPCB 1989

4.2.1.1. Pollution by large industries

In 1992, the CPCB has launched a water pollution control program in order to tackle the problem of industrial pollution. It has identified 1551 large and medium industries, and given a time schedule for compliance with the prescribed standards.
The progress report is presented in the following tables. According to these figures, a drastic reduction can be observed in the number of non-compliant industries. Doubts main remain, however, concerning the actual operation of the installed treatment units. There are indeed evidence that many industries only run their effluent treatment plant (ETP) during the inspections.

Table 8 Status of Pollution Control in 17 Categories of Highly Polluting Industries, India, 1995 and 2000

State/ Union territory	Number of units identified	No. of units not having adequate facilities to comply with standards	
		Mar-95	Dec-2000
Andhra Pradesh	173	32	1
Assam	15	5	1
Bihar	62	11	2
Goa	6	0	0
Gujarat	177	8	0
Haryana	43	7	0
Himachal Pradesh	9	0	0
Jammu and Kashmir	8	4	0

Karnataka	85	21	0
Kerala	28	4	0
Madhya Pradesh	78	21	5
Maharashtra	335	28	5
Orissa	23	10	4
Punjab	45	11	0
Rajasthan	49	2	0
Tamil Nadu	119	8	0
Uttar Pradesh	224	40	3
West Bengal	58	27	3
Delhi	5	3	0
Pondicherry	6	4	0
Other states/UT	3	6	0
Total	**1551**	**252**	**24**

Source: Central Pollution Control Board, Annual Report, 1994-95 and 2000-01, reported in Goldar and Banerjee 2002.

Table 9 Status of Defaulters under the Program of Industrial Pollution Control Along the Rivers and Lakes, India, 1997 and 2000

State/Union Territory	Number of defaulters in Aug. 97	Closed subsequently	Acquired requisite treatment/ disposal facilities	Number of defaulters in Dec.2000
Andhra Pradesh	60	17	37	6
Assam	7	5	0	2
Bihar	14	4	10	0
Goa	0	0	0	0
Gujarat	17	3	14	0
Haryana	21	8	12	1
Himachal Pradesh	0	0	0	0
Jammu and Kashmir	0	0	0	0
Karnataka	20	2	17	1
Kerala	36	4	32	0
Madhya Pradesh	2	1	0	1
Maharashtra	6	3	3	0
Orissa	9	1	4	4
Punjab	18	1	16	1
Rajasthan	0	0	0	0
Tamil Nadu	366	118	248	0
Uttar Pradesh	241	59	176	6
West Bengal	30	7	23	0
Pondicherry	4	0	4	0
Total	**851**	**233**	**596**	**22**

Source: Central Pollution Control Board, reported in Goldar and Banerjee 2002.

4.2.1.2. Pollution by Small scale industries

As mentioned in section 2, the toughest choice that Indian authorities have to face in term of industrial pollution control is posed by pollution small scale industries (SSIs). Indeed, the smallest facilities are the one for which adaptation to the environmental standard are less affordable. The number of SSIs is estimated to be over 0.32 million units, of which many are highly polluting. The share of the SSIs in term of wastewater generation among several of the major polluting industries was reported to be about 40%.

Table 10 Wastewater generation by SSIs in selected industrial sectors

Industry	Wastewater generation (MLD)
Engineering	2125
paper and board mills	1087
textile	450
organic chemicals	60

tanneries	50
pharmaceuticals	40
dye and dye intermediates	32
soaps, paints, varnishes, and petrochemicals	10
edible oiol and vanaspati	7

Source : CPCB, reported in Kathuria and Gundimeda (2001)

4.2.2. Estimation of Pollution Intensity in India using the Industrial Pollution Projection System.

In order to deal with the lack of global data about industrial pollution in developing countries, the World Bank has developed a method to assess such levels of pollution, using data from developed countries such as the US and converting them, thanks to pollution intensities coefficients (Hettige et. al., 1994). This method is called Industrial Pollution Projection System (IPPS).

The IPPS has developed by the World Bank merges data from US-EPA about pollution emissions and the Longitudinal Research Database (LRD) on industrial activity, in order to calculate a pollution intensity for different industrial sectors. The pollution intensity is defined as the level of pollution emission per unit of industrial activity, this last value being measured either by the value of production, the value added, or the employment. The pollution intensities from the World Bank have been computed for the year 1987.

Recently, an attempt has been made to estimate industrial pollution in India using the IPPS (Pandey & Gosh, 2002).

The data used were provided by the Annual Survey of Industries (ASI) from the Indian Central Statistical Organisation (CSO).

Thanks to these datas, Pandey & Gosh were able to give an estimation of the pollution load in the different states and the contribution of the different polluting industries to this pollution load in each states.

The estimated pollution load for the different states is presented in the following table.

Table 11 Water Pollution Load (tons of BOD) Using Output intensity.

States	Pollution Load
Bihar	321494
Madhya Pradesh	243125
Maharashtra	234360
Orissa	204240
Andhra Pradesh	131536
West Bengal	130444
Uttar Pradesh	103205
Punjab	96050
Tamil Nadu	84384
Gujarat	78354
Karnataka	58705
Haryana	36939
Rajasthan	23530
Delhi	12387
Pondicherry	9655
Chandigarh	9294
Assam	7861

Kerala	6549
Himachal Pradesh	5709
Jammu & Kashmir	2378
Goa	118
Daman & Diu	115
Others	78698
All India	1879140

Source : Pandey & Ghosh, 2002.

The following table provides some estimations of Pollution Load for the different industries.

Table 12 Estimated water pollution load (in tons) by industry.

Industry	Estimates using Output Intensities	Ranking	Estimates using Employment Intensities	Ranking
Aluminium	47469	3	0	16
Copper	16035	6	44495	9
Zinc	7737	8	22923	12
Iron and Steel	1639368	1	8093409	1
Cement	5168	11	28000	11
Oil Refinery	4340	12	16805	13
Drugs	5889	10	44736	8
Petrochemicals	1818	13	3805	14
Fertilisers	31480	4	106644	7
Pesticides	7366	9	37927	10
Caustic Soda	836	15	135691	5
Pulp and Paper	86245	2	801764	3
Leather	894	14	5316058	2
Dyes	0	16	1198	15
Distillery	7740	7	110334	6
Sugar	16747	5	217639	4

Source : Pandey & Ghosh

4.3. Pollution by agricultural run-offs

Pollution by agricultural run-offs has too main effects on the environment. Pesticides may be responsible for poisoning. They are specially difficult to remove from freshwater, and thus, can be found in municipal or bottled water, even after conventional treatment. A study from the CSE recently drew the alarm about the concentration in pesticides such as organochlorines and organophosphaters that was exceeding the WHO standards in almost all the Indian brands of bottled water.

(Down to Earth, February 2003, www.cseindia.org/html/lab/bottled_water_result.htm)

As for the fertlisers, they have an indirect adverse impact on the water resources. Indeed, by increasing the nutritional content of the water courses, fertilisers allow organisms to proliferate. These organisms may be disease vectors, or algae. The proliferation of algae may slower the flow in the water courses, thus increasing again the proliferation of organisms and sedimentation.

In spite of these well known adverse effects, and the worrying growth of fertiliser and pesticide use in the India agricultural sector, these products are still subsidised by the government.

The following table shows the increasing use of fertiliser and pesticide in the country.

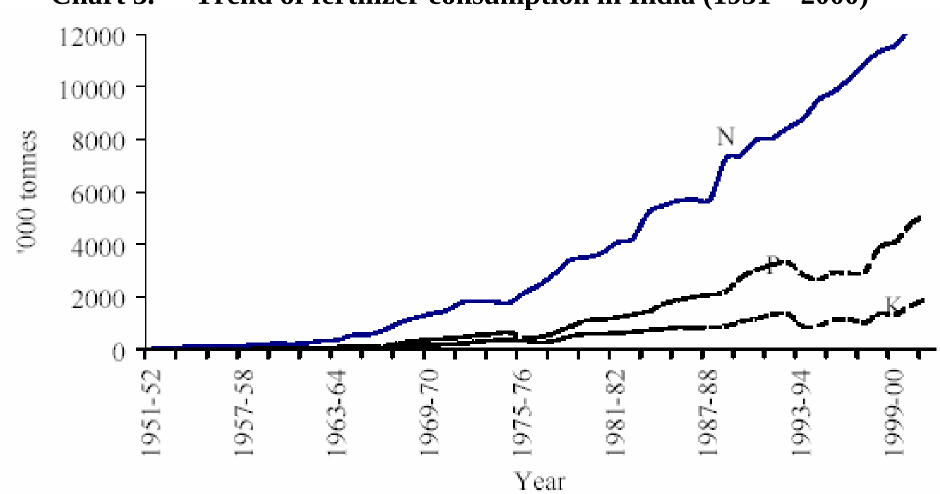
Table 13 Evolution of fertiliser and pesticide use in India.

Fertiliser Use (Million of tones)		
1984	7.7	
1995-96	13.9	(80 % increase)
Pesticide Use (tones)		
1971	24305	
1994-95	85030	(240% increase)

Source : Central Statistical Organisation, 1999 (reported in IGIDR, 2000)

The following chart shows a detailed profile of the evolution of the consumption of the three major chemicals used in fertilisers, i.e. Nitrates (N) Phosphates (P), and Potassium (K).

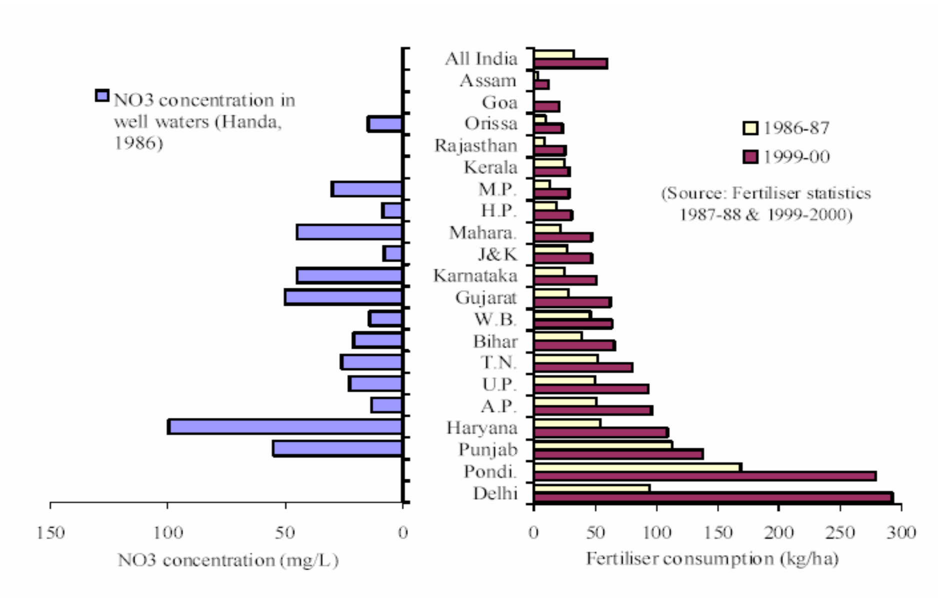
Chart 3. Trend of fertilizer consumption in India (1951 – 2000)



Source : Bathnagar & Sharma, 2002

The WHO has defined a permissible limit of concentration of Nitrates of 45 mg/L of NO3, which is also accepted by the Indian Council of Medical Research (ICMR).
The following chart shows the relation between N-Fertilisers in several states and the respective concentration of NO3 found in tubewells during a survey carried out in 1986.
It can be observed that in states such as Haryana, the NO3 concentration was already exceeding by far the permissible limits in 1986. The increase in fertilisers consumption reported in the right part of the chart leads us to assume that those concentrations are now exceeding the limits in several other states.

Chart 4. N-Fertiliser consumption and NO3 concentration in major states and union territories in India.



Source : Bathnagar & Sharma 2002.

5. Adverse economic impacts of water pollution – Existing studies on India

This section presents four attempts at assessing the potential economic benefits from pollution control, or presented differently, the cost of environmental degradation that could be avoided through pollution control.
The first study was carried out by a team from the World Bank (Brandon & Homman, 1995) and presents an assessment of the nation-wide health cost of water pollution in India. It is in fact an assessment of the negative health impact of domestic pollution that could be avoided through extending the coverage of clean water supply and sanitation to all the population. The economic impact is calculated with data provided by the "Global Burden of Disease" project (Murray & Lopez, 1996; WDR 1993), using the human capital approach.
The second study (Misra, 1999) applies a radically different approach. First, it is a micro study, the field of study being the rural and urban areas surrounding the Nandesari Industrial Estate in the state of Gujarat . The second difference lies in the method of assessment. In this study, the potential benefit of pollution control is assessed through stated preferences. This method is called Contingent Valuation Method (CVM). People are asked to give a willingness to pay for the increase in both user an non-user value of the environmental goods that would be the output of a pollution control policy.
The third study (Mirkyanda & Murty, 2000) is also a local study, since it is a cost-benefit analysis of an implemented project of environmental protection : the ganga action plan. It provides results derived from both direct (CVM) and undirect approaches.
The fourth study (Appassamy et. al. 2002) is also a micro study, the field of study being the Noyyal River Basin in Tamil Nadu. It applies an undirect method of economic valuation as in the Brandon & Homman study, but the cost studied here are different. The study provides three main costs of water pollution which are loss of agricultural productivity, higher cost of water supply, and loss of production in fisheries. Moreover, the pollution whose effects are analysed here is also different. Indeed, the study focuses on the effect of the concentration of Total Dissolved Solids (TDS), a type of pollution which is not removed by conventional Effluent Treatment Plants.

The goal of this literature review will not be to compare the aggregate figures presented in those different studies, since they apply to different scales. It will rather be to identify the assumption and methods used for valuation, and the individual values obtained, in order to see how and why the results may differ from one to another.

5.1. The cost of inaction (Brandon & Homman 1995)

The more recent attempt at providing a comprehensive analysis of the cost of environmental degradation in India is a study carried out by two experts from the World Bank in 1995. This study's ambition was not to provide precise figures, but to provide gross but comprehensive estimates of the different economic burden put on India by environmental degradation.

5.1.1. General Results

Low and High Estimate were provided for the different costs, which have the merit of giving a confidence index in the precision of the figures.
Concerning water pollution, one should notice than the only quantified cost was the health burden due to domestic pollution. This cost was calculated as the achievable reduction of infectious and viral water related diseases achievable with full water supply and sanitation coverage. The main missing costs are then : the health cost of chemical pollution, the higher cost of

municipal water supply, the cost of treatment for industries, and the loss of agricultural productivity due to bad water quality.

Table 14 Summary of major Annual Environment Costs in India (Brandon & Homman 1995)

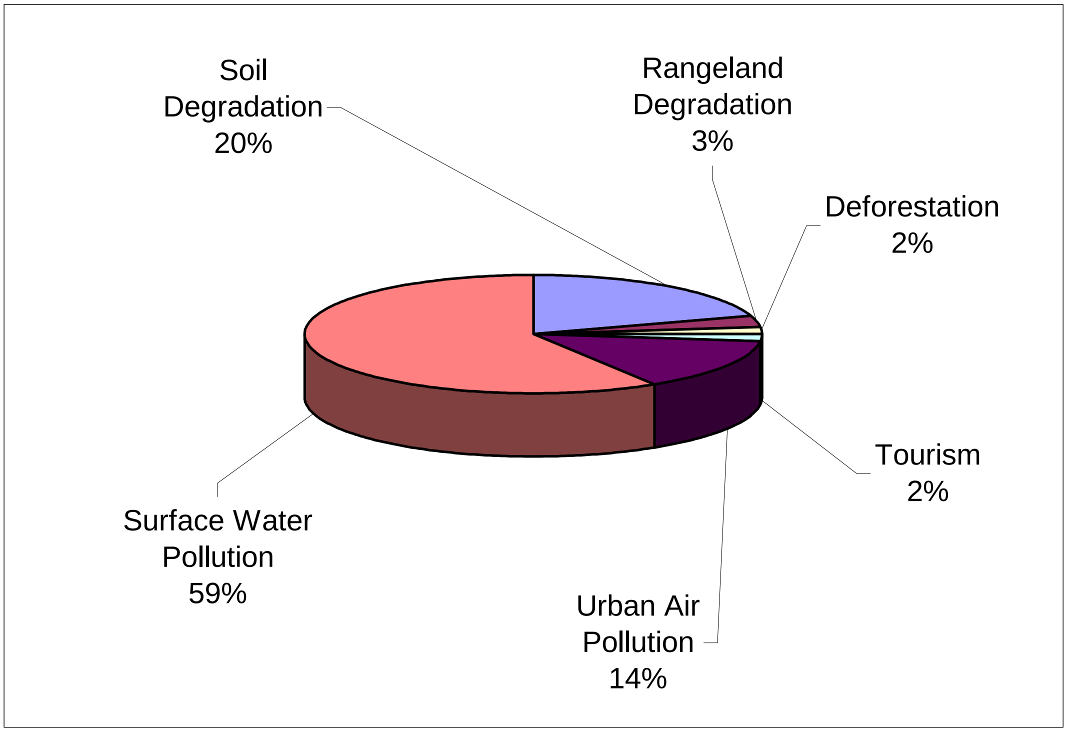
Problem	Impacts on health and/ or production	Low estimate (millions US$)	High Estimate (millions US$)
Urban Air Pollution	Urban health impacts	517	2102
Water Pollution (health impacts)	Urban and rural health impacts, esp. Diarrheal diseases	3076	8344
Water Pollution (Production impacts)	Higher incremental costs for clean water supply	not estimated	not estimated
Industrial Hazardous Waste	Long-term health impacts, esp. Cancer	not estimated	not estimated
Soil Degradation	Loss of agricultural output	1516	2368
Rangeland Degradation	Loss of livestock carrying capacity	238	417
Deforestation	Loss of sustainable timber supply	183	244
Coastal and marine resources	Unsustainable harvesting of marine resources	not estimated	not estimated
Loss of biodiversity	Loss of use, option, and existence values	not estimated	not estimated
Tourism	Decline in tourism revenues	142	283
Total Costs of Environmental Degradation		5672	13758
Total cost as % of GDP		2.64%	6.41%
Average Total Cost		9.715	
Average Total Cost as % of GDP		4.53%	

Source : Brandon & Homman, 1995

The estimate of average cost as percentage of GDP as high as 4.53 % of the GDP for 1992 can be compared to such estimates for other countries. The figure for China has been estimated at 2.6 percent of the country's GDP, for Mexico at 3.3%, upto 5% for countries in eastern Europe, and less than 1-2% for industrialised nations. (CSE, 1997)

The results presented in the last table are summarized in the following chart, which shows the great importance of water pollution in the overall burden of environmental degradation in India.

Chart 5. Summary of the Major Annual Environmental Costs for India [Total = US$ 9.7 billion]



Source : Brandon & Homman, 1995

5.1.2. Calculation method for the Health Cost of Water pollution.

The figures given for the health cost of water pollution in the Brandon-Hommann report are in fact quite different from what could be thought of as the real cost of water pollution, i.e. the health status due to actual ambient water quality compared to an hypothetical health status with good ambient water quality, everything else remaining the same (infrastructures, private behaviour, etc…).

Indeed, the cost provided in the report is the health impact that could be avoided, provided full water supply and sanitation coverage.

We will however present the main assumptions and estimates used in this calculation.

The calculation of the health cost of water pollution took a certain range of water-related diseases and derived from it a certain economic burden. The diseases taken into account were: diarrhea, trachoma, intestinal worms, hepatitis, and the "tropical cluster" of diseases. These diseases' occurrence is mainly related to domestic pollution. Therefore, the health cost given in the Brandon-Hommann report can be interpreted as the cost of domestic pollution, letting aside the health costs of industrial and agricultural pollution.

The most important water-related health cost omitted in this report should then be associated to cancer occurrence due to chemical pollution such as high concentration of pesticides in drinking water. However, no quantitative assessment of the link between chemical pollution (industrial as well as agricultural) and health is available for India, which justifies the decision of the authors not to give a cost for industrial pollution.

The data used in the report for the water related health impacts was the figures presented in the World Development Report (WDR) 1993. Those figures were expressed in Disabilities Adjusted Life Years (DALYs) The meaning of DALYs is detailed in section 5.2.2. of this report : "Measuring the burden of disease".
The WDR 1993 gave a figure of 30.51 millions of DALYs lost in the year 1990 due to water-related diseases.

A value was then attributed to the DALY's, using the human capital approach. This means that attempts were made to deduce a global aggregate of wage loss due to disease from the global DALY's provided in the WDR 1993. A low estimate was 215$, a medium estimate was 330$, and a higher estimate was 570$.

In order to assess the impact on health of improved water supply and sanitation, the authors used the result of a meta-analysis conducted by the WHO in 1991 (Esrey et. Al.) which found that improved water supply and sanitation produced a median reduction in morbidity and mortality on the order of 25% for morbidity and 65% for mortality.

The following figures concerning access to drinking water and sanitation were used :

Table 15 Access to drinking Water and Sanitation in India, 1980 and 1990

	Urban	Rural	Total
Water Supply			
1980	77%	31%	42%
1990	86%	69%	73%
Sanitation			
1980	27%	1%	7%
1990	44%	3%	4%

Source : WDR 1994

Different set of asssumptions were then made on :

- The relative impact of water supply vs. sanitation in health improvement. The impact of water supply was assumed to greater or equal (relative importance between 0.9 and 0.5) to the one of sanitation coverage. (This assumption is quite questionable, see for example Esrey et. al. 1985 and 1991).
- The correlation between water supply and sanitation provision and hygiene. A positive correlation was assumed, accounting for people with better services are supposed to have better hygiene practiced than the one without access to these services.

5.1.3. Impact on the cost of water supply.

No valuation of the increased cost of water supply was provided in the study. However, a study carried out by the UNDP-WorldBank Water and Sanitation Program (WSP) in 1993 was mentioned. This study showed a global trend of increase of the cost of water supply projects by two to three time from a unit to another (Bhatia et. al., 1993).
Even attributing a small share of this additional cost to water pollution would lead to considerable amounts.

5.2. Measuring Benefits from Industrial Water Pollution Abatement: Use of Contingent Valuation Method in Nandesari Industrial Area.

This study was carried out to assess the potential benefits from pollution abatement in the Nandesari Industrial Estate in the state of Gujarat. Two separate questionnaires were used to assess the willingness to pay (WTP)for environmental protection from urban and rural populations. Both user and non-user value were assessed.
The urban survey covered 386 households for user value and 366 households for non-user value.
The estimated average WTP was of Rs. 74 per capita per annum for user value and Rs. 57 for non-user value.
The rural survey covered six villages having a population of 7890 households. 405 household were covered for user value, giving an average estimate of the WTA equivalent to Rs. 2709 per capita per annum.

This disparity in the willingness to pay between the urban and rural household reveals how rural household are more directly exposed to the adverse effects of environmental degradation. While the urban disutility of water pollution is linked to an hypothetical increased risk of contamination of drinking water, the rural disutility caused by the same degradation can be expressed in terms of loss of revenue due to a decrease in agricultural productivity, as well as a direct increase in the health risk associated to contaminated water.
One can wonder, for example if the urban population takes into account the additional cost of water supply they have to bear when answering the questionnaire. If this is not the case, then, the results obtained do not give the full extent of the potential benefits from pollution abatement, leaving aside the cost of water supply.

5.3. Cleaning-up the ganges: a cost-benefit analysis of the Ganga Action Plan.

This study (Markyanda & Murty, 2000) is an attempt at valuing the outcome of an ongoing project of environmental rehabilitation : the Ganga Action Plan (GAP). This action plan was presented in section 2.6. When the study was done, Rs. 7045.40 million had been spent under the GAP Phase I, and Rs. 611.97 under the GAP Phase II. An attempt is made at comparing assessed benefits from the action plan to these costs.

The quality level was summarized by an indicator calculated using the different BOD concentration at different point of the Ganga.

5.3.1. Contingent Valuation Survey

A first assessment of benefits is done through valuation of user and non-user benefits associated to different levels of river quality : (1) the initial level of water quality before the implementation of the GAP, (2) the actual level of water quality at the time of the study, (3) the targeted final level of river quality targeted, corresponding to bathing use.

The survey on non-user value gave an average willingness to pay for the different river quality attributable to the 8.7 million households from the urban literate population in the 23 class I cities (with a population over 1 million).
This measured willingness to pay was of :

- Rs. 101.48 per annum per household for the past quality (1985).
- Rs. 192.81 per annum per household for the current quality (1995).
- Rs. 557.94 per annum per household for bathing quality.

The survey of user benefits aimed at giving an average per household per annum WTP for all the household living within 1 km of the river banks.
The survey gave an average willingness to pay of :

- Rs. 93.28 per annum per household for the past quality (1985).
- Rs. 167.23 per annum per household for the current quality (1995).
- Rs. 581.59 per annum per household for bathing quality.

The similarity between user and non-user value may explained by the fact that the population concerned by the non-user value estimation are in average wealthier than the one concerned by the user-value estimation.

5.3.2. Health Benefits

The positive health impact from the GAP were calculated based on the results of a study carried out by the All India Institute of Hygiene and Public Health (AIIH&PH, 1997) about the improvements to users' income due to reduction in working days lost, and the additional cost of treatment of water for public supply without implementation of GAP

According to the survey carried out by the AIIH&PH, the following health benefits were inferred in six cities on the Ganga banks :

Table 16 Health benefits from reduced loss of working days

Town	Average No of working days saved yearly per family	Regular Users of Ganga in town (No of families)	Individual daily income	Total value (Rs. Millions)
Hardwar	6.09	41300	64	16
Kanpur	3.42	15560	35	1.86
Patna	6.58	22480	88	12.94
Chandannagar	6.44	5690	38	1.37
Nabadwip	7.37	4760	65	2.28
Titagarh	2.61	4920	31	0.39

Source : AIIH&PH, 1997

The study also tried to assess the additional cost of treatment that the cities would have had to bear if the GAP had not been implemented. Assuming the need for an additional treatment using the activated carbon absorption technique.
The assumed cost was of Rs. 3000 per million litres.

5.3.3. Impact of the residual toxicants on agriculture, health and the environment.

This part of the study deals with the impact of toxicants such as metals and pesticides that are not removed by theconventional Sewage Treatment Plants (STPs) set up within the GAP. It studies the impact of high concentration of these compounds in the areas receiving effluents from STPs.
Although no economic valuation of the impact was done, it was observed that the population living in areas receiving effluents from STPs had a much greater exposure to risk due to intake of heavy metals and pesticides.
No significant impact of residual pesticides and heavy metal on agriculture was found in this study.

5.3.4. Impact of on fisheries and agriculture

An attempt was made at valuing the positive impact of water quality improvement on fisheries outcome. A positive correlation between water quality improvement and catches was found, but no quantitative estimate of the impact was done due to the lack of data.
The impact on agriculture calculated in the study can not be linked to a cost of pollution since it mainly analyses the positive impacts of by-products from the GAP such as irrigation with wastewater from STPs, or use of sludge as fertilizer.

5.4. Environmental impact of industrial effluents in Noyyal River Basin.

A local assessment of the economic impact of industrial pollution has been carried out by a team of economists from the Madras School of Economics (MSE) (Appassamy et. al., 2002).
This study focuses on the impact of pollution in terms of Total Disolved solids (TDS), since this pollution is not controlled through conventional ETPs.
The studied showed that in the case of the Noyyal River Basin, the insufficient assimilative capacity of the hydrological sytem leads to residual TDS concentration attributable to effluents from the ETPs of the various industries from the area that have a significant impact on the different users.

5.4.1. Impact on the agricultural sector

Based on a survey carried out by the Soil Survey and Land Use Organisation (SS&LUO), areas were classified as normal, moderately affected, or severely affected.
The classification was based on results of test of Electrical Conductivity (EC) applied to water samples from the different areas.
The water quality of samples were categorized as :

- Normal for EC < 1 mmhos/cm
- Moderately Affected for 1 < EC < 3 mmhos/cm
- Severely Affected for EC > 3 mmhos

It was observed that higher proportion of fertilizers had to be used in the affected areas.

The output per acre in affected areas was around one third of the one in unaffected areas.
It was 50% lower in moderately affected areas than in unaffected areas.

Certain crops such as paddy could not be cultivated anymore in affected areas.

5.4.2. Impact on drinking water

Both rural and urban water supply were dealt with.
For rural water supply, an average travel cost of water fetching was estimated at 1.20 hours a day per household. Taking an average wage rate per day for agricultural labour of Rs. 54, the travel cost accounts for an annual cost of RS. 3888.
However, no differential estimation of this travel cost between affected and non affected zones was performed.

For urban water supply, the case of the Tirrupur municipality was studied.

Tiruppur municipality has increasingly had to rely on external sources for drinking water since local sources are either polluted or unsufficient. The latest scheme proposes to bring 185 mld of water from the cauvery river at a cost Rs. 252 crore.

5.4.3. Impact on fisheries

In a former studied carried out by the Madras School of Economics a valuation of fisheries loss had been performed.Catch from one reservoir and 29 tanks were studied, and the total loss was estimated at Rs. 0.5 crores.

6. The cost of pollution control

6.1. The cost of Industrial Pollution abatement

The goal of a pollution control policy is to get as close as possible to the state that maximises the aggregated social welfare. Considering the level of pollution, the highest social wellfare should be obtained by pollution abatement until the point at which the marginal abatement cost and the marginal environmental damage avoided through this abatement have the same value. Identifying such a point would imply to know precisely the aggregated abatement cost function of the national industry. Therefore, studying the cost of industrial pollution abatement is a critical element in defining an economically and ecologically sound policy for pollution control.
There have been several studies carried out by Indian academics during the 90's in order to provide information about the cost of compliance with environmental standards for the Indian Industry.

6.1.1. General figures

In a brief paper prepared by IGIDR for the UNDP, general estimates of the cost of pollution abatement the Indian Industry may have to bear are provided. Nevertheless the signification of these figures is difficult to understand since the specification of the hypothetical scenario, especially in terms of ambient pollution standard, are not detailed in the paper. We therefore assume that those figures are referring to a scenario where all polluting industries were complying with the existing pollution standards.
It is estimated that Indian industry may have to spend around 2 to 5 % of its capital investment on pollution control. The annual operating costs are expected to be between 15 to 30 per cent of the investment made on the treatment facilities.
According to these estimates, the total annual investment needed for water pollution abatement across all the water polluting industries is estimated at R. 1400 crores, which is about 1.17M of the annual turnover of these industries.

6.1.2. Indian studies on abatement cost functions.

6.1.2.1. Mehta, Mundle & Sankar, 1993

The first attempt by Indian academics to present a cost of pollution abatement for a certain kind industry was presented in Mehta, Mundle & Sankar, 1993. Three industries among the one considered by the Indian regulatory system as pollutiong industries were selected for the study; i.e. sugar, distilleries, and paper.
The three pollution indicators taken into account were Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH, and Suspended Solids (SS).

The following average abatement costs were found from the analysis of 22 sample units.

Table 17 Average Abatement Cost in Sample Units (1991-1992 Prices)

	Sugar	Paper	Distilleries
Capital cost per KLDF* (Rs.)	1900	949	11260
Annualised capital cost per KLDF (Rs.)	352	175	2088

Annualised capital cost per sale ratio (%)	0.26	0.63	3.52
Operating cost per KL efflent flow (Rs.)	1.74	0.82	3.17
Operating cost per kg reduction of pollutants (Rs.)	4.27	2.25	0.07
Operating cost to sale ratio (%)	0.4	0.7	0.85
Net operating cost to sale ration (%)	0.4	0.56	-4.6
Labour cost share in operating cost (%)	14.4	6.71	19.1
Material cost share in operating cost (%)	14	15.5	44.2
Power cost share in operating cost (%)	70	66.52	31.6

* KLDF stands for Kilo Liter Designed Flow
Source : Mehta, Mundle & Sankar, 1993

Using a technical study on the paper industry (Subrahmanyam 1990), and primary data from NEERI and NIPFP, the authors constructed an abatement cost function for the paper industry. Since BOD was found to be the limiting factor, the abatement cost function was constructed as the cost function of reducing BOD. This simplification is a common convention in the analysis of water treatment costs.

Two forms of the abatement cost function were proposed:

$$C = e^{a} F^{b} I^{c} E^{g} \quad (1)$$
$$C = e^{a} F^{b} I^{c} e^{gE} \quad (2)$$

Where
C = Operating cost of waste water treatment
F = flow size of the waste water stream
E = concentration of pollutants in the influent stream
I = concentration of pollutants in the effluent stream

Equation (1) has the classical form of a Cobb Douglas Function, which is a popular choice of functional form for abatement cost functions.
Equation (2) was proposed to correct the problem of C tending to infinity in the case of E falling to zero.
Both equations were tested with the data set and used to provide marginal abatement costs (MAC) in ruppes per 100g reduction in effluent BOD. The MAC were calculated at the level of reduction needed to achieve the MINAS standards laid down by the CPCB for pulp and paper industries releasing their effluents in rivers (50 mg/L).
The MAC presented hereunder were calculated for different level of F and E. The results are presented for maximal, average, and minimal values of F and E. Results obtained with equation (1) and (2) are presented together.

Table 18 Estimates of Marginal Cost per 100g BOD to Achieve MINAS Level of BOD (50mg/litre)
(Rs. / 100 g of BOD at 1991-92 prices).

Flow of Wate Water (KL/D)	Marginal Cost					
	Equation (1)			Equation (2)		
	Influent Concentration (mg/L)			Influent Concentration (mg/L)		
	Min (190)	Max (500)	Ave (330)	Min (190)	Max (500)	Ave (330)

Minimum (5400)	0.61	1.36	0.97	0.65	1.42	1.02
Maximum (55540)	0.18	0.4	0.29	0.21	0.46	0.33
Average (32256)	0.24	0.53	0.38	0.27	0.6	0.43

Source : Mehta, Mundle & Sankar, 1993

Using these results, the authors stated that if a market-based approach to industrial pollution control was to be implemented in India, charges between Rs. 1.35 to Rs. 1.45 per 100 grams BOD reduction should be fixed in order to achieve the objective of the current MINAS standards.

6.1.2.2. James & Murty, 1996

The second attempts by James & Murty in 1996 was based of a questionnaire-based survey for 131 firms from 10 major industrial states in the country. The final size of the sample used for the estimation of pollution abatement cost was 82.

Different estimations of MAC were tried with BOD and COD as the principal indicator of pollution. The waste water volume was allowed to vary in order to determine the extent of the economies of scale.

Finally, estimations using COD were selected because of the better fit of this specification to the data, and tax rates were calculated for an effluent concentration equal to the MINAS standards, i.e. 250 mg/L.

Table 19 Tax rates in Rupees for 100g reduction in COD per Annum (1993-1994 prices):

	Maximum Volume	Average Volume	Median Volume
Maximum CODINF*	0.1	0.41	8.08
Median CODINF*	0.06	0.24	4.82

CODINF is the concentration of COD in the ifnluent.

Source : James & Murty 1996

6.1.2.3. Pandey, 1997

In this study, Pandey tried to estimate an abatement cost function for the sugar industry in India. The author used a Cobb-Douglas model for the cost function, similar to the one used formerly by Mehta, Mundle & Sankar (1993), as well as Murty & James (1996). She added a variable to the model by differentiating the volume of effluent of the effluent treatment plant (ETP) and the volume of influent entering the ETP that actually come from the industrial process. Indeed, it was noticed that since the MINAS laid down by the CPCB takes into account only the concentration of the effluent, and not the volume of these effluent, a way to comply with the standard may be to dilute the effluents with fresh water. In this case, the volume of effluent released by the ECP, is different from the volume of effluent from the industrial facility.

With regard to this perverse incentive to water consumption, a logical recommendation was formulated to express MINAS standards in terms of mg of pollutants rather than in milligrams per liter.

The data used in this study is in respect of 53 firms. It was obtained through an Environment Engineering Consultant who had designed and commissioned ETP's in various sugar firms.

Table 20 Marginal cost of removal of 100 g of BOD at the MINAS level for Effluent concentration (30 mg/L)

	Marginal Cost		
Flow of Waste Water (KL)	Influent Concentration in BOD (mg/L)		
	Minimum (600)	Average (992.45)	Maximum (1200)
Minimum (500)	1.22	1.55	1.69
Average (1335.8)	0.93	1.18	1.3
Maximum (2500)	0.79	1	1.09

Compiled from Pandey 1997.

The suggested tax rate that was deduced from these figures was of Rs. 1.69 per 100 g pf BOD at 1993-1994 prices, to be levied on per 100 g of extra BOD beyond MINAS (30 mg/l of BOD)

6.1.2.4. Roy & Ganguli, 1997

In their attempt at determining an abatement cost function for the pulp and paper industry in India, Roy and Ganguli used secondary data provided by the Bureau of Industrial Cost and Prices, now part of the tariff commission, under the Ministry of Commerce and Industry, Government of India.
The study tried to estimate the marginal cost of BOD removal, using a data set covering 11 large pulp and paper mills with production varying from 40 Metric tonnes (MT)/ day to 300MT/day.

Table 21 Marginal costs in rupees for reduction in 100 grams of BOD for maintaining standard at 30 mg/L

Flow of Wate Water (KL/Annum)	Marginal Cost		
	Influent Concentration in BOD (mg/L)		
	80	289	1200
Minimum (1831500)	6.88	5.68	8.52
Maximum (24209100)	1.54	1.27	1.91

Source : Roy & Ganguli 1997

6.1.2.5. Goldar & Pandey, 1999

This study uses methods similar to the one applied in the former studies. Cross section data for 44 distilleries for the year 1996/97 was used for estimating the cost function. The model of abatement cost function was similar to the one used in Pandey 1997.

The marginal cost of abatement for 100 g of BOD was found to be equal to Rs. 3.47 for a concentration level of the ETP effluents equal to the MINAS (30 mg/L).

The study then used a Programming Exercise in order to investigate the incentive to dilute the effluent produced by different environmental tax schemes, and assessed the cost of water extraction for dillution purpose.

6.1.2.6. Murty & Kumar, 2001 a.

In this study, the author apply an original method to assess an abatement cost function for the suga r industry. The method applied is called the distance function approach.
In this method, pollutants are considered as undesirable and non-marketed outputs of the productive activity. The distance function approach is used to analyse the productive efficiency of the firms. Fir-specific shadow prices are put on the pollutants, which allows estimating the marginal abatement cost functions given the firm-specific data about pollution loads and concentrations.

The data used in this study were obtained through surveys of polluting industries in India conducted by the IEG during the years 1996 and 2000.
For the sugar industry, the data include information about 60 firms for the year 1994-1995 and about 120 firms for the years 1996-1997, 1997-1998, and 1998-1999.

Tax levels expressed in Rs. per metric ton were proposed for the three main pollutants : BOD, COD, and SS.

Table 22 Pollution Taxes for the Sugar Industry for Realizing MINAS Standards for Water Pollution (30 mg/L for BOD, 250 mg/L for COD, and 100mg/L for SS)

	BOD	COD	SS
Tax (per metric ton in rupees)	23518	45567	7605

Source : Murty and Kumar 2001

6.2. The cost of domestic pollution control

6.2.1. Urban Wastewater

The following table provides an estimate o the cost structure of the different technique of sewage treatment for urban wastewater.

Table 23 Costs of domestic wastewater treatment.

Technology	**Land Required** *Hectares/mld*	**Capital Costs** *Lakh ruppes/mld*	**Operation & maintenance costs** *Lakh rupees/mld/year*
Activated Sludge Treatment Plant (ASTP)	0.4	35 to 40	3.0
Oxidation Ponds	1.0	12 to 15	0.5
Aerated Lagoons	0.6	15 to 20	2.75
Upward Anaerobic Sludge Blanke	0.2	23 to 28	1.5
Duckweed and fish culture technology	0.7-1.0	10 to 12	0.5 to 1.0
Karnal technology	1.0 - 1.5	0.6 to 0.8	0.25 to 0.3
Trickling filter	0.4	35 to 40	3.0

Source Ministry of Environment and Forests, 1998

6.2.2. Rural Wastewater

In the World Development Report 1993, India was reported to have on of the lowest coverage in the world with a rate around 15%.

The coverage of rural population was estimated to be at a level of 17% at the beginning of the ninth plan (1997) and grew of 3% during the ninth plan.

Rural Sanitation policies are undertaken by states government and are supplemented by the Central Government under the Centrally Sponsored Rural Sanitation Programme (CRSP), launched in 1986.

Table 24 Financial and physical of rural sanitation programmes

Plan Period	CRSP (GoI) Release (Rs. In Crore)	State Sector Expenditure	Latrines constructed
Eight Plan Period	260.33	497.29	4337609
Ninth Plan Period			
1997-1998	96.66	168.48	1387080
1998-1999	64.90	189.27	1630922

7. Conclusion

This study allowed us to have a general view of the efforts taken in India to understand the economic implication of water pollution. The measurement of pollution in river flows and underground reservoirs developed during the last decades and it is now possible to have an overview of the ambient water quality in the country thanks to a network of around 500 monitoring stations. The information available is expressed using the ambient quality standards defined by the CPCB and does not allow a real analysis of the water pollution problem, nevertheless it shows clearly that pollution is exceeding the standards in many places. The only attempt at giving a nation-wide cost of water pollution is the study carried out by Brandon & Homman [1995]. We saw that the figures provided are only rough estimates. Moreover, the cost provided is only deduced from the overall figures on diarrhoeal diseases occurrence in the country, and lets aside many other significant costs. Nevertheless, even if underestimated, the figure of 4.53% of GDP for the total cost of pollution, with surface water pollution accounting for 59% of it has the merit of being clear. India cannot afford not to deal with water pollution. The rough results provided by Brandon & Homman may be enriched with the comparison with similar although more local studies. Three other studies were reviewed in this report, each of them applying a different method in order to put a price on environmental change. The study carried out by Misra (1999) showed results from a survey using the contingent valuation method (CVM) in order to assess the willingness to pay of local population from in the surrounding of an industrial area for an improvement in ambient water quality. CVM was also applied in an attempt at valuing the benefits from the Ganga Action Plan (Markyanda & Murty, 2000). A method more similar to the one applied by Brandon & Homman was used in Appasamy et. al (2002) were several type of costs (health, agriculture and fisheries productivity) were calculated in the case of the Noyyal river basin in Majarashtra.

The second type of studies reviewed dealt with costs of pollution reduction. Most of the academic work done in this field deals with industrial pollution. Several methods have been applied in order to estimate pollution abatement function for different sectors of the Indian industry. Nevertheless, very few information is available on the cost of controlling other types of pollution such as domestic pollution and especially agricultural pollution.

We can conclude this survey by noticing that in the political as well as in the academic spheres, much attention has been paid to the control of industrial pollution so far. Although advances in this field have to be sustained, it is necessary to take measures to tackle the problems arising from other and more complex sources of pollution such as uncollected domestic wastewater or agricultural run-off.

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Annex A

1. The health cost of water pollution – methodological issues.

It is generally recognized that the main economic burden associated with water pollution is the effect of pollution on health. Nevertheless, giving a cost of water pollution due to its adverse health effects is far from being an easy task.
Valuing the health impact of pollution implies, first, to identify and measure the health impacts that can be attributed to a certain state of pollution, and then to give a monetary value to these impacts.
The first task should ideally give a function giving a relation between morbidity* and mortality* associated with a certain set of diseases, and the measured level of the available pollution indicators. This kind of relationships have been studied in the case of air pollution and some Dose-Response Relationships (DRRs) have been provided through several case studies[7]. The second task can then be achieved provided a method that allows giving an economic value to morbidity and mortality of a certain individual given its social characteristics. Several methods can be applied for this stage, which will be discussed.

1.1.1. Possible health impacts of water pollution.

Two different environmental risk factors can be related to water pollution, the first one being lack of access to clean water, sanitation and hygiene (WSH), and the second one being agro-industrial pollution. Those two risks may have an impact on different sets of diseases.

The first risk will have an impact on the occurrence of various kind of diseases that can be classified in three categories:
Water-borne diseases: the organism responsible for the disease may be transmitted through water.
Water-washed diseases: contamination occurs due to a lack of hygiene.
Water-based diseases: water is a medium for part of the disease's vector (mosquitos, flies) life cycle.
These diseases include :
Amoebiasis, Cholera, Conjunctivis, Dengue*, Diarrhea, Dysentery, Filariasis*, Giardiasis, Guinea worm*, Helicobater Pylori, Helminths, Hepatitis A,E, Japanese encephalitis*, Malaria*, Onchocerciasis*, Poliomyelitis, Rotavirus, Scabies, Schistosomiasis*, Trachoma, Chagas, Typhoid, Leptospirosis, Yellow Fever*.
(* Diseases usually refered to as belonging to the Tropical Cluster, mainly water-based)

The second risk is associated to a very different set of diseases that include :
Liver and pancreas cancer, meanomas and other skin cancers, lymphomas and multiple myeloma, endocrine disorders, unipolar major depresssion, cataracts, nephritis and nephrosis, rheumaoid arthritis, congenital anomalies, poisoning.

1.1.2. Measuring the burden of disease.

Given a certain disease, two basic data may be available concerning the impact of a this disease on a given population. The fist one is the mortality associated to this disease, that is, for an

[7] For an Indian exemple, see : Cropper M.L., Simon N.B., Alberini A., Sharma P.K., (1997) "The Health Effects of Air Pollution In Delhi, India." Policy Research Working Paper 1860. World Bank, Development Economics Research Group, Washington D.C.

individual from a certain population, the chance to die from the specified disease. The second one is morbidity, which reflects the chance to get infected by the disease. The WHO and the World Bank have undertaken a joint exercise in order to provide global estimates of the burden of disease. In order to provide a standardized measure of health outcomes, a new indicator, DALYs (for Disability Adujsted Life Years) was been developed by the WHO (see Murray & Lopez 1996). A first compilation of data from all countries, covering the major causes of illness was done with the 1990 data and was presented in the 1993 World Development Report : "Investing in Health".
DALYs combines life years lost due to premature death and fractions of years of healthy life lost as a result of illness or disability. A weighting function that incorporates discounting is used for years of life list at each age to reflect the different social weights that are usually given to illness and premature mortality at different ages.

The following table. presents the 1990 figures of the burden of disease in millions of DALYs lost for India.

Table 25 India: Burden of Disease in 1990

	Males		Females		Total		Rank
DALYs	**DALYs**	**%**	**DALYs**	**%**	**DALYs**	**%**	
Total DALYs lost, thousands	**146091**	**100**	**146698**	**100**	**292789**	**100**	
Communicable, Maternal and Perinatal Causes	**71690**	**49.1**	**77805**	**53**	**149495**	**51.1**	
Tuberculosis	6282	4.3	4518	3.1	10800	3.7	11
STDs	30	0.4	3203	2.2	3733	1.3	18
HIV	2707	1.9	1358	0.9	4065	1.4	16
Diarrheal Disease	13643	9.3	14394	9.8	28037	9.6	3
Childhood Cluster	9579	6.6	9874	6.7	19453	6.6	6
Meningitis	1191	0.8	815	0.6	2006	0.7	23
Hepatitis	143	0.1	168	0.1	311	0.1	28
Malaria	4760	3.3	4750	3.2	9510	3.2	12
Tropical Cluster	1479	1	966	0.7	2445	0.8	20
Leprosy	259	0.2	262	0.2	521	0.2	27
Trachoma	112	0.1	197	0.1	309	0.1	29
Intestinal Helminthes	1056	0.7	1000	0.7	2056	0.7	22
Respiratory Infections	15568	10.7	16186	11	31754	10.8	1
Maternal Causes	0	0	7824	5.3	7824	2.7	15
Perinatal Causes	14381	9.8	12290	8.4	26671	9.1	4
Noncommunicable Causes	**59625**	**40.8**	**56942**	**38.8**	**116567**	**39.8**	
Malignant Neoplasms	6633	4.5	5409	3.7	12042	4.1	9
Diabetes Mellitus	840	0.6	1028	0.7	1868	0.6	24
Nutritional and Endocrine Causes	9183	6.3	9082	6.2	18265	6.2	7
Neuropsychiatric	9426	6.5	8411	5.7	17837	6.1	8
Sense Organ (mainly eye)	1238	0.8	1146	0.8	2384	0.8	21
Cardiovascular	14732	10.1	13860	9.4	28592	9.8	2
Respiratory	3900	2.7	4006	2.7	7906	2.7	14

Digestive	5607	3.8	5634	3.8	11241	3.8	10
Genitourinary	1884	1.3	2048	1.4	3932	1.3	17
Musculoskelatal	405	0.3	849	0.6	1254	0.4	26
Congenital Abnormalities	4843	3.3	4590	3.1	9433	3.2	13
Oral Health	934	0.6	879	0.6	1813	0.6	25
Injuries	**14776**	**10.1**	**11951**	**8.1**	**26727**	**9.1**	
Unintentional	12640	8.7	10494	7.2	23134	7.9	5
Intentional	2136	1.5	1457	1	3593	1.2	19
Source: World Development Report, 1993							

1.1.3. Assesment of the health impact of water pollution.

In the process of assessing the health impact of pollution, the different kind of pollution, namely air pollution and water pollution do not set the same challenges.

The first difference between air pollution and water pollution is the uniformity of the pollution. Indeed, it can be assumed that air pollution is more or less uniform on a certain area, whereas water quality may differ greatly within a small area following the location of pollution sources.

The second difference is the linkage between the ambient quality and the characteristics of the air breathed or the water ingested. Indeed, in can be assumed that within a specified area where air pollution is considered as uniform, everyone breath the same air, whereas several external factors may have an influence on the quality of water ingested by individuals. The complexity of this process is illustrated in chart 1

Therefore, if Dose-Response Relationships (DRRs) have been established for different air pollutants in different areas, in the case of water pollution this task is far more complicated, and very few studies have been done to provide with DRRs for water pollutants.

Moreover, whereas health problems due to air pollution can be related directly to the quality of the air breathed and isolated from other respiratory diseases, most of the health problems due to water pollution can find their source in other characteristics than the quality of drinking water. Indeed, most of the water-related diseases can also be transmitted through food, hand contact, insects, etc… (see Curtis, Cairncross & Yonli 2000)

This has recently led several institutions to call for a more holistic approach of the Water, Sanitation, and Hygiene problems than the conventional one focusing on drinking water supply.

WASH (WAter, Sanitation and Hygiene) : a need to change the agenda.
The Water Supply and Sanitation Collaborative Council (WSSCC) launched a campaign of promotion of an integrated approach towards mitigation of health risks related to unsafe water, sanitation and hygiene (WASH). The campaign sheds the light on several misconceptions that have led to inefficient policies. Among them are classical negative trends such as top-down and supply driven approaches, and the belief that water can be considered as a free good to be delivered by politicians. But the WASH campaign also draws the attention on other mistakes such as the priority given to water supply over sanitation, and to sanitation over hygiene, or the belief that collective installations offer better cost effectiveness. Indeed, it has been observed that public latrines often prove to be very little used, and can be source of disputes. Another mistake mentioned is the underestimation of the quantity of water actually needed by an household to ensure and healthy environment. Indeed, while basic needs for safe drinking water can be estimated arund 25 L/day, if the quantity of water needed for hygiene is included in these basic needs, it leads to minimum of 250 L/day for an household of six people. This shows that if drinking water can be provided at common point relatively distant from the households, there is a need for water sources suitable for hygiene at a very lower distance.
This means that the real benefits for health can only be achieved through the simultaneous provision of:

1. Water quality: Households must have a source of fresh water suitable for consumption purposes, or some in-house technologies of purification (filters or chemicals).
2. Sanitation: The actual behavior of communities has to be taken into account and the facilities supplied must have the necessary characteristics to be used by the targeted populations.
3. Water quantity: On side of water for drinking purposes, a certain quantity of water suitable for hygiene purposes must be available at a distance that does not put an excessive cost on hygienic behaviors.
4. Hygiene education: Populations have to be aware of the impact on health of practices such as water storage, food conservation and hygiene.

Therefore, very little information is available to assess the real relationship between the observed morbidity and mortality due to potential waterborne diseases, and the ambient water pollution.

Chart 6. Linkage between ambient water quality and health.

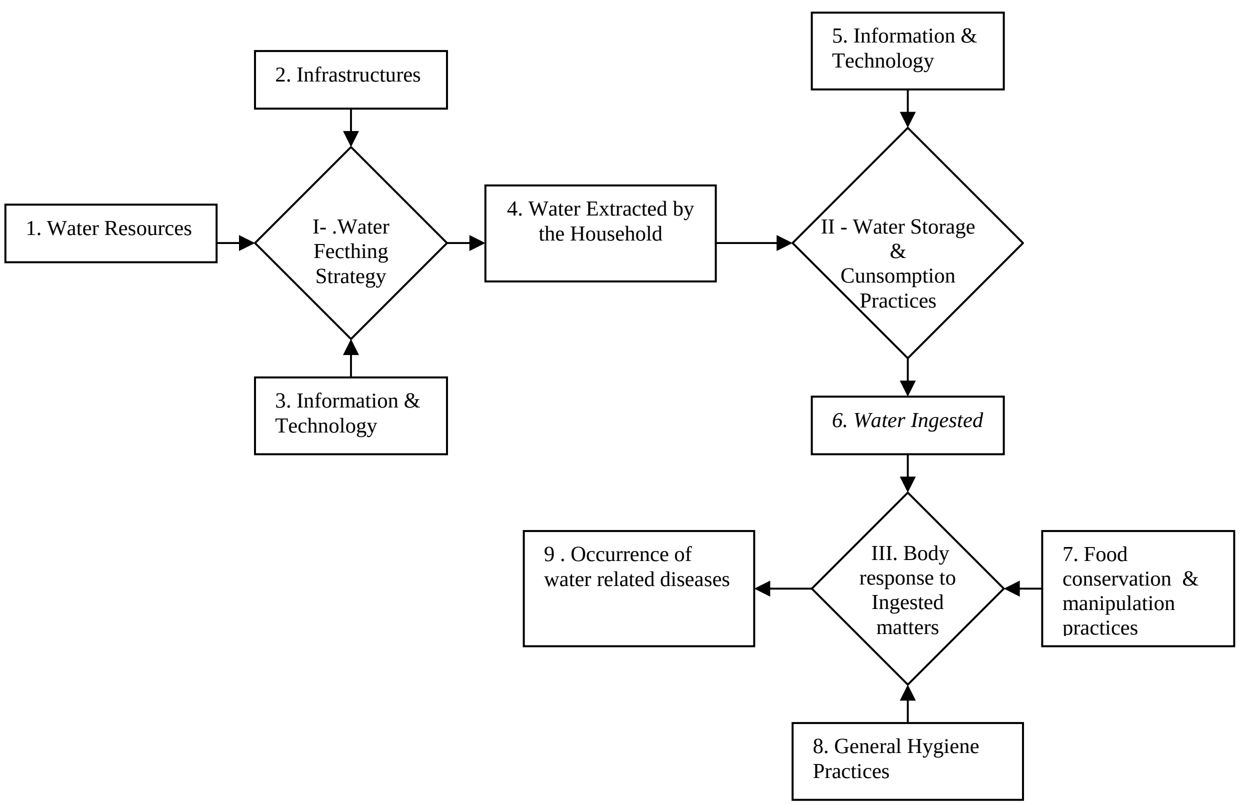

Chart 1. Provides with an illustration of the complexity of the process linking the ambient water quality and the health of people using the water resources.
Indeed, it shows how external factors may have an influence in the process at three different stages which are :

I - the water fetching strategy
II - the water conservation and consumption practices
III - the body's response to ingested matters

Indeed, at the first stage, the water fetching strategy (I) of a certain household does not only depends on the characteristics (quantity, quality, geographical repartition) of the different water resources (1). Indeed, it also depends on the infrastructures that have been developped for the extraction and distribution of water (2), but also on the information and technology available within the household (3). The information may be information about the characteristics of the water resources and the related infrastructures, or the effect of water quality on health. Based on this information, each household will elaborate a water fetching strategy defined by the choice of the water resources to be used, the technology used for water fetching, etc…
The output of this first stage is the bulk water actually available to the household (4).

One in the household, the quality of water will be influenced by the storage practices , and the actual quality of the water entering the body will depend of the ambient cleanliness of the household (III).
The output of this second stage is the amount and quality of water entering the body (6).

Once in the body, the water may cause some diseases that can also be caused by other sources such as contaminated food (7) or dirty hands (8).

Only the combined health impact of these different factors (9) can be observed as the occurrence of what is generally referred to as "water, sanitation and hygiene – related diseases".

1.1.4. Empirical studies about the impact of WSH on health.

In 1991, the WHO did a meta-analysis using 144 studies (Esrey, Potash, Roberts, & Shiff, 1991) in order to determine the effect of improved water supply and sanitation on major water – related diseases such as Ascariasis, Diarrhoea, Dracunculiasis, Hookworm Infection, Schistosomiasis, and Trachoma. The study showed that improving the two factors together produced a median reduction of 25% for morbidity and 65% for mortality.

A study carried out by the world bank in Brasil attempted at using epidemiologic data in order to determine the impact of water and sanitation on infant and under-five mortality. It found high influence of factors such as household income, or women education level. Urbanisation also was found to have an impact on infant and under-five mortality. Other factors being held constant, mortality is higher in urban areas.
The study finally gave impact rates for 10% improvement in Urban access to piped water and sewers. These figures illustrate the relative importance of these two factors.

Change per 10 Percentage rise in:	Infant Mortality	Under-five mortality .
Urban access to piped water	0.8	0.25
Urban access to sewers	0.6	0.15
Average mortality rate	39.4	8.8 .

In the a background paper on health and environment from the world bank (Lvovsky et. al, 2001) assumptions about the contributions from specific disease to the general global burden of disease attributable to the WSH risk factor were proposed.
These were :

Table 26 Burden of specific disease attributable to the WSH risk factor

Diarrheal diseases	80%
Hepatitis	30%
H. Pylori	20%
Trachoma	25%
Intestinal helminths	70%

Source : Lvovsky et. al., 2001

The same study provided with general figures about the burden of disease attributable to the main environmental riks for the different regions of the world.
These figures were obtained by compiling datas from several WHO and WB studies from the early 90's.

Table 27 Burden of disease from major environmental risks.

	Percent of all DALY's in each country group								
Environmental health group	SSA	India	Asia & Pacific	China	MNA	LAC	FSE	ICs	All DCs
Water supply & sanitation	10	9	8	3.5	8	5.5	1.5	1	7
Vector diseases (malaria, etc.)	9	0.5	1.5	0	0.3	0	0	0	3
Indoor air pollution	5.5	6	5	3.5	1.7	0.5	0	0	4
Urban air pollution	1	2	2	4.5	3	3	3	1	2
Agro-industrial waste	1	1	1	1.5	1	2	2	2.5	1
All causes	26.5	18.5	17.5	13	14	11	6.5	4.5	18

Notes : SSA is Subsaharian Africa, LAC is Latin Americ and Caribbean, MNA is Middle East and North Africa, Ics stands for industrialised countries, and DCs is developing countries.

Source : Lvovsky et. al., 2001

1.1.5. Valuation of the health impacts.

The valuation method used to put a price on health impacts can be classified in two main categories, which are indirect market or revealed preference methods, and direct market or stated preference methods.

Revealed preference methods include:

- The cost of illness approach, which sums the revenues lost due to the disease, and the cost of treatment.
- The Human Capital, which takes into account the earnings forgone due to premature death. The cost of illness and human capital approach can be considered as complementary since the first deals with morbidity and the second with mortality in similar ways.

- The averting behavior approach, which sums the cost of actions to avoid a pollutant In the case of water pollution, the cost of treating river water for urban supply, the investement in a private purification facility, or the purchase of bottled water can be considered as preventive costs, as well as the travel cost implied by the need to fetch water in distant non-polluted sources.
- The hedonic pricing method, which takes as an indicator the variability in market prices of a certain kind of goods attributable to the level of environmental risk that is associated with these goods. The hedonic pricing method may be applied to the labor market. In this case, the value of reduction of risk to health in otherwise similar occupations is observed. This method is usually referred to as the compensating wage differential method.

Stated preference methods include:

- Contingent valuation studies, in which people are asked about their willingness to pay (WTP) to avoid a certain risk of disease or death. (Mitchell & Carson, 1989)
- Contingent averting behavior studies, in which people are asked about the actions they might take to avoid a certain risk if they were confronted to it.
- Conjoint analysis, for which people are asked to rank a certain number of situation with different levels of spending, risks, etc.