Green Accounting for Indian States Project

Monograph 8

Accounting for Freshwater Quality in India

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GIST Green Indian States Trust

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September 2007

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GAISP (Green Accounting for Indian States Project)

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Published by
TERI Press
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Darbari Seth Block
IHC Complex
Lodhi Road
New Delhi – 110 003
India

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Acknowledgements
The authors would like to express their sincere gratitude to Mr Lalit Kumar, Senior Lecturer in Business Economics at the BRA College, University of Delhi, for his support with data and analysis and compilation of information. Virginia Hooper (Research Associate, GIST), provided critical research support to this project. We are thankful to her for this. We also thank Dr Giles Atkinson from the London School of Economics and Dr Nilanjan Ghosh (then at IIM [Indian Institute of Management] Kolkota and TERI) for their constructive suggestions and comments. Mr P Yeshuthasen, Trustee, GIST, deserves special thanks for his valuable support and guidance on administrative and financial issues. We also thank TERI Press for their help.

Printed in India at Multiplexus India, Delhi

Contents

List of acronyms

BOD	biochemical oxygen demand
CGWB	Central Ground Water Board
COD	chemical oxygen demand
CPCB	Central Pollution Control Board
GAISP	Green Accounting for Indian States and Union Territories Project
GDP	gross domestic product
GNP	gross national product
GSDP	gross state domestic product
MAR	mean annual run-off
MPN	most probable number
NAMEA	National Accounting Matrix Environmental Accounting
SEEA	System of Environment and Economic Accounting
SNA	System of National Accounts
TDS	total dissolved solid
TVC	total variable count

Accounting for freshwater quality in India

Background

In common with most developing nations, India faces many trade-offs in its attempt to reduce poverty and enhance the living standards of its people. There is a need for an empirical basis on which to base policy decisions on trade-offs between the many competing priorities of a developing nation, including inter-generational claims (trade-offs between the needs of present and future generations). Available measures of development, including the current SNA (System of National Accounts) of the United Nations with its primary focus on GDP (gross domestic product) growth rates, do not capture many vital aspects of national wealth, such as changes in the quality of health, changes in the extent of education, and changes in the quality and extent of environmental resources. All of these aspects significantly impact on the well-being of India's citizens generally, and most of these are critical to poverty alleviation specifically, providing income opportunities and livelihood security for the poor. GDP accounts and their state-level equivalents – GSDP (gross state domestic product) accounts – are therefore, inadequate as toolkits for comprehensively evaluating the trade-offs encountered by policy-makers in India.

The 'Green Accounting for Indian States and Union Territories Project' or GAISP was constituted in 2004 largely in recognition of the reality that though 'GDP growth percentages' are substantially misleading as yardsticks of growth, development, wealth or well-being, planners, policy-makers, businesses, and the media continue to use them extensively, even uniquely. GAISP proposes to build a framework of adjusted national accounts that represents genuine net additions to national wealth. These are sometimes referred to as 'green accounts' in relevant literature. Such a system of environmentally-adjusted NIAs (national income accounts) will not only reflect in economic terms the depletion of natural resources and the health costs of pollution but will also reward additions to the stock of human capital through education. Green accounts for India and its states will provide a much better measure of development than GDP (national income) growth percentages and GSDP (state income) growth measures and will encourage the emergence of sustainable development as a focus of economic policy at the operative state level.

GAISP aims to set up top-down economic models for state-wise annual estimates of adjusted GSDP for all major Indian states and Union Territory economies. A top-down or macroeconomic approach is adapted to model adjustments to GDP/GSDP accounts, for two reasons. First, it has the advantage of providing a consistent and impartial national framework to value hitherto unaccounted aspects of national and state wealth and production. Second, it optimizes the existing research, which is already extensive but not yet tied together in a manner that makes it useful for policy analysis. The publication of the results and methodology of GAISP will provide a much-improved toolkit for India's policy-makers to evaluate in economic terms the trade-offs they face. It will also engage policy-makers and the public in a debate on the sustainability of economic growth, both at a national level as well as through inter-state comparisons.

The first phase of GAISP comprises the publication of the following eight monographs, each of which evaluates a particular area or related set of areas of adjustments to GSDP accounts.

1 The value of timber, carbon, fuelwood, and non-timber forest produce in India's forests
2 Estimating the value of agricultural cropland and pasture land in India
3 The value of India's sub-soil assets
4 The value of biodiversity in India's forests
5 Estimating the value of educational capital formation in India
6 Investments in health and pollution control and their value to India
7 Accounting for the ecological services of Indian forests: soil conservation, water augmentation, and flood prevention
8 Accounting for freshwater quality in India

All adjustments calculated in these monographs apply to the same set of GSDP accounts (year ended March 2003) and are additive. GAISP's website <www.gistindia.org> will feature a running record of cumulative state-wise adjustments to these GSDP accounts. To a first-order approximation, these adjustments may be added or subtracted as indicated to GSDP growth percentages for 2002/03. The final report of GAISP will summarize and consolidate the work done on these eight monographs and include 'adjusted GSDP' measures for the states and significant union territories comprising India, as well as provide a commentary on the policy implications of the results.

Accounting for freshwater quality in India

Introduction

Water is one of the fundamental natural resources on which the sustenance of society depends. Though marine water has its own role to play, it is the quantity and quality of fresh water that are of primary importance to society. In the context of a typical ecosystem, water has a dual role—it is not only a service from ecosystems but also a rich ecosystem in itself (MA 2005). In this monograph, water has been considered as a provisioning output used for irrigation, drinking, and industry.

Precise estimation of the availability of fresh water at global and national levels is quite complex, although estimates fall within the range of 33 500–47 000 km^3 (cubic kilometres) per year at the global level. This is long-term mean run-off (Doll, Kaspar, and Lehner 2003; Shiklomanov and Rodda 2003). Water is the most challenging resource that can be manipulated into an accounting framework due to its intrinsic properties. It flows, changes state, and is available seasonally. In addition, a large portion of the water theoretically available, is bound up in ice and snow or runs off the surface as floods. When compiling water accounts, it is important to understand the hydrological cycle and describe what the hydrological system means within a territory of reference. The hydrological or water cycle has been defined as 'the succession of stages through which water passes from the atmosphere to the earth and back to the atmosphere: evaporation from the land or sea or inland water, condensation from clouds, precipitation, accumulation in the soil or in bodies of water, and re-evaporation' (UNESCO, cited in MA 2005).

In order to prepare accounts of water assets under the United Nations System of National Accounts (also known as SEEA [System of Environment and Economic Accounting]), the asset classification of water resources in SEEA should reflect those components of the hydrological system that are available for water abstraction and provide direct input into the economy.

Although the interaction between the economy and the water sector is obvious, a clear-cut understanding of the relationship is important from the accounting point of view. Figure 1 provides the schematic of the conceptual linkages between water and economic sectors.

The economy returns water to the hydrological system through various flows including returns of waste water to aquifers, rivers, lakes, and oceans; returns to soil and water bodies from irrigation activities; and losses in transportation (supply, sewerage pipes, and so on). These return flows are an input to the hydrological system and become a resource (even if often of lower quality) for subsequent uses. Imports/exports of water to and from the economy are considered as direct inflows/outflows of water

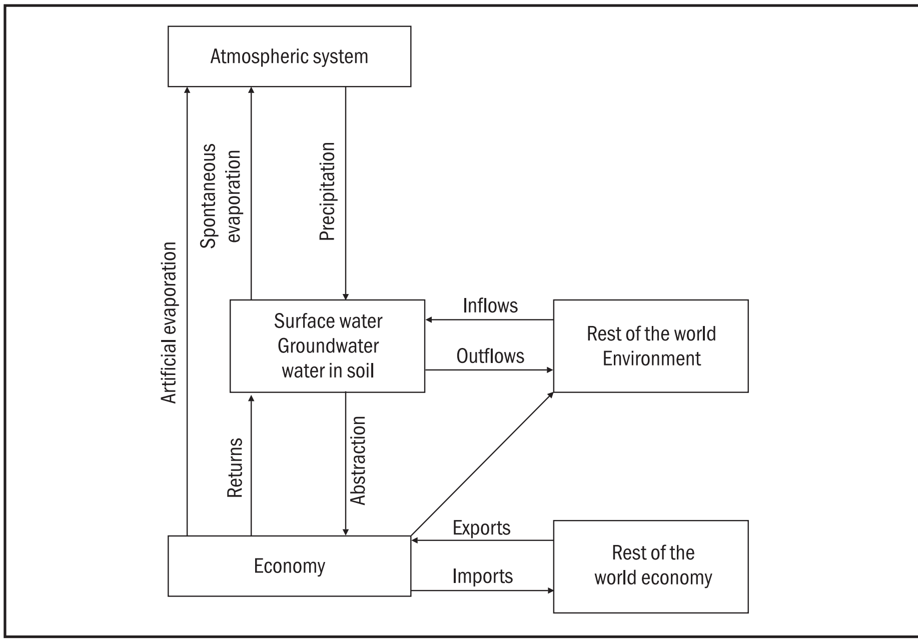

Figure 1

Economy–water interaction

through pipes from and to the economies of other territories. These days, export of primary products – especially foodgrains, meat, and dairy products – are also considered as export/import of water, which is known as 'virtual water'. However, we have not considered this aspect in the current monograph.

Growing concerns about water scarcity and water quality issues have led to the documentation of the flows of water within and between the environment and the economy. This has been achieved by formatting data about water into standard accounting tables. Organizations such as the United Nations and Eurostat have made guidelines to enable countries to prepare accounts for water, which are similar in structure and, therefore, comparable.

Accounting for water and the estimation of the depletion of freshwater stocks and degradation of water quality help in rectifying the asymmetry between the adjustment of depreciation of man-made and natural capital. Calculation of sustainable GNP (gross national product), commonly known as green accounting, clearly provides rationale for estimation and adjustment of depreciation of natural capital against the conventional national income accounts (Bartlemus, Stahmer, and Tongeren 1998; Common and Stagl 2005; Hamilton 1998; Pearce, Markandya, and Barbier 1989)

Scope of the monograph

This monograph first describes the popular types of accounting usually followed in case of freshwater resources. Second, it reviews some of the successful examples of accounting done in select countries from all over the world and focuses on lessons learnt from doing such an exercise in a developing country like India. Third, the change in the quality of water over the period 1993–2003 has been computed for surface water and groundwater. Fourth, the deviation from the national standard (acceptable limit) has been calculated. Fifth, the costs of necessary intervention on account of incremental pollution from the acceptable limit have been estimated by following the replacement costs couched in mitigating expenditure method. Here, different technologies, their efficacy, and so on have been given due consideration. We get a range of values of averting expenditure and the average has been calculated. This figure has been equated with the damage to the water resources of the country during 1993–2003. And finally, they have been adjusted against the net state domestic product for Indian states and union territories.

Types of water accounts

Water accounts need to follow the principles of both the economy and the hydrological cycle. They exclude flows of water that exist solely within the environment and concentrate on water available for extraction. There are two main accounting tables used in the national and state water accounts: asset classification tables and physical flow accounts. Usually, supply and use tables are also produced, but this monograph does not focus on them.

Asset classification These tables include those sources of water, which are available for abstraction and use within the economy. They comprise opening and closing accounts that document the flow of water to and from the environment and within the economy.

Physical flow accounts These accounts describe the whole system of flow of water between the environment and the economy, and within the economy. The hydrological cycle suggests that water can be found in many forms, from vapour through to ice. For economic purposes, water is only considered when it is available for extraction. These supplies include groundwater and different categories of surface water like rivers, lakes, reservoirs, and dams.

Some basic concepts

It is relatively simple to calculate the amount of water available in lakes, dams, and reservoirs compared to groundwater and rivers. Groundwater not only flows but the size and porosity of aquifers (and hence the total available volume of water) can be difficult to determine. To gain a complete understanding of a particular aquifer requires expensive investigation, so often, simple models and approximations are used. For rivers, two methods can be used to calculate the volume of water. The first uses the volume of the river channel as a proxy for water volume. This can be problematic for ephemeral rivers, and so the MAR (mean annual run-off) may be used instead. This discharge figure is more accurate, although more difficult to measure, as a number of measurements must be taken over the course of the year.

Most countries do not include water trapped in the soil or snowfields or water held as glaciers in their accounts because in general, this water cannot be abstracted. There are, however, exceptions depending on the particular scenario in a given country. For example, in countries where snowmelt contributes to water supplies later in the year, snowfields are included as stocks.

The asset classification tables focus on precipitation, inflows from other countries, and outflows to the sea as well as abstraction and residual returns. A hidden but substantial loss of water occurs through the evaporation from water bodies, plants, and soil. It is, therefore, important to describe precipitation net of evapotranspiration or include evapotranspiration as a loss from the water supply.

The quantity of water available for use will, on average, remain the same year on year. This is because the average precipitation remains the same. In other words, water is a renewable resource in terms of volume. The exception is groundwater. These stocks are replenished by recharge from precipitation that infiltrates into aquifers. These resources can be considered to be 'mined' or used as a non-renewable resource if extraction occurs faster than recharge. A second example of 'mining' groundwater occurs if the aquifer is geologically confined and cannot be naturally recharged.

Quality vs quantity accounts

Assessing water quality in terms of an accounting framework requires consideration of the number of different uses that water can be put to. Obviously, water used as an industrial coolant need not have the same quality as water used for drinking or bathing. Thus, water can have a number of economic uses before it is finally discharged back to the environment. Ideally, these different quality requirements should be reflected in the accounts. On paper, quality accounts are very similar to quantity accounts. SEEA and Eurostat guidelines essentially describe the same method for compiling these tables. Water quality is measured over a number of criteria (relevant to the particular state or country), for example, BOD (biochemical oxygen demand) or total coliforms. Acceptable levels of these pollutants are set for different quality classes of water. These quality classes are assigned to volumes of water and the information can be represented in a table that is very similar to the tables for quantity.

The simplicity of the tables masks the difficulties involved in assigning quality measurements to flowing water. These issues are still being resolved, although the method used by the IFEN (French Institute for Environment) (standard river units method) has produced good results in France. There remain problems, however, in terms of the spatial and temporal variations in water quality, which need to be represented in the accounts.

Review of literature

Water accounts published by different countries vary enormously in both their scope and focus. This lack of consistency reflects the availability of data and the specific water-related issues (determined, for example, by climate, the type of industry, and the provision of waste water treatment) in a particular country. The purpose of this review is to compare how both the quantity and quality of fresh water have been assessed in a selection of countries and to give a brief overview of any additional information provided in the reports published by these countries.

Many of the published water accounts are affected by a lack of relevant data and, understandably, focus on the areas where there is most information. For example, in New Zealand, the accounts (produced by Statistics New Zealand) include detailed studies on every aspect of freshwater stocks including snow, glaciers, and soil water, but as yet have not incorporated water quality in an accounting framework (Woods and Henderson 2003; Statistics New Zealand 2004)

Measuring the quantity and quality of inland water is difficult because of the flowing nature of water (rivers and groundwater), the temporal variations in groundwater reserves and river discharge, and the logistics of creating a suitable sampling network. These factors are complicated further because agencies tend to collect information in terms of different geographical regions (river basins, water authorities or states), and it is difficult to compare these data sets with one another.

Australia has published water accounts since the mid-1990s. Water resources are of great concern because of the continued depletion of groundwater reserves and the recent severe drought. Many of these reserves are being used in an unsustainable manner and this will undoubtedly cause problems for future generations. The aim of the water accounts is to create opening and closing stocks of the total amount of water in terms of both surface water and groundwater, and then to assemble supply and use tables (flow tables) for industry and domestic use. The accounts are based on the framework suggested by the SNA (System of National Accounts) 1993 and SEEA 2003 reports. Although most of the information is collected on a river basin scale, the data has been collated by state to provide a more informative picture.

Water stocks are represented by the surface water and groundwater asset tables, which are combined to form annual water balance tables. The amount of water stored in dams is also included in the annual water balance.

Surface water is measured by considering MAR. This is measured as the discharge of the river at a specified point and gives a good approximation of total surface flow. Considerations of the temporal variation in water flow (due to seasonal changes in precipitation and evaporation) are incorporated into the results. The water flow tables indicate the amount of water supplied from the environment to industry, households, and the government. The amount of water returned to the environment from these sectors is also assessed (McLennan 2000).

Eventually, Australia would like to incorporate an assessment of water quality into their annual water accounts. The latest accounts (2000/01) have included an assessment of groundwater quality in terms of salinity, but this has not been fully incorporated into the accounting framework as yet (Trewin 2004).

Sweden is yet another significant example that does accounting for fresh water. The country has produced physical environment accounts since 1993. It first attempted to compile water accounts in 1999 by using data from 1995 and followed the NAMEA (National Accounting Matrix Environmental Accounting) framework. The accounts concerned the physical quantity of water flowing within the environment and the economy, and did not include an assessment of water quality (Branvall, Eriksson, Johansson, *et al.* 1999). New accounts for 2000 have now been published and include more detailed information. The new account structure follows the water accounting guidelines developed by Eurostat.

The main focus of the accounts is the construction of supply and the use of tables for physical and monetary data with respect to water abstraction, use, waste water generation, and waste water treatment. In comparison with other countries, such as New Zealand and South Africa, a great deal of attention has been paid to assessing both the cost of the water supplied to the user and the cost of water treatment.

Sweden abstracts large quantities of water from the sea, which is used as a coolant in the power industry. Sea water abstraction is, therefore, included in the national accounts; this aspect of water resource accounting is quite different from many countries where only inland water systems are represented in the accounting system (although Denmark also included sea water and the UK defines coastal water as a resource) (Eurostat and the European Commission 2002). Sweden also chooses to disregard water used by the hydropower industry from its national accounts. This is because it is the potential energy of water that is deemed to be the commodity rather than water itself. This is in direct contrast to New Zealand where water from hydro-generation companies constitutes a large part of the accounts.

The Swedish accounts include detailed assessments according to industry type. There is information on the amount of water abstracted and used by each industry, the quantity of waste water discharged, and measurements of the levels of four different pollutants within this water.

As with many of the national water account initiatives, there are omissions caused by lack of data. For example, no recent surveys have been conducted into the amount of water required for irrigation and livestock. Branvall, Eriksson, Johansson, *et al.* (1999) have used irrigation data from 1985 and produced an estimate for livestock through analysis of the number and type of livestock currently being raised in Sweden (analogous to the method used in New Zealand). The report also acknowledges that there is little data with which to evaluate expenditure on 'own abstraction of water' by industry.

Water quality issues have received a significant amount of attention in Sweden, where there are strict water quality targets that are due to be met by 2015. There is particular concern about the quality of the water discharged to the sea and its effect on the sustainability of aquatic ecosystems. However, the quality of the inland water has not been measured in a systematic manner (as compared to attempts in South Africa and France); instead, data related to the composition of waste water discharged from industry and water treatment plants has been collected. The report focuses on the levels of BOD, COD (chemical oxygen demand), N (nitrogen), and P (phosphorus) in water. These constitute emission (or discharge) accounts and although they are undoubtedly informative, they do not have the scope that direct measurements of water quality would allow.

In the Mediterranean region, Spain's account for fresh water is worth mentioning. Water resources in Spain are under severe strain due to expansions in agriculture and tourism (two industries that are heavily reliant on water). The future of these industries is dependent upon good water resource management. For example, in 1999, over 70% of the total water used was for irrigation.

Spain has produced water satellite accounts for 1999 based on the NAMEA framework. Physical water accounts are in terms of four different sectors. They consider the abstraction, use, supply, and demand of water, and the discharge of waste water into the rivers. Data can also be found from 1997 to 2001 on the balance of water movements between the economy and the environment for different economic activities.

The Spanish accounts reviewed here have not attempted to quantify the total stocks of water in Spain in terms of surface water, groundwater or other categories of water. No mention has been made of balancing items such as evapotranspiration from crops or the incorporation of water into products. Instead, the accounts focus on the total amount abstracted for each industry and the type of water abstracted (that is, suitable for drinking, industry, and so on).

Water quality has been addressed in the form of emission accounts of waste water and the composition of this water in terms of metals (total), N, P, BOD, and COD. Where possible, this data has been divided into regions. For example, there are tables of water use by state (Instituto Nacional 2001).

South Africa has produced both water quantity and quality accounts for 2000. The aim is to eventually combine these reports into an overall water account, but this has not been achieved yet. The accounts suffer from lack of available data with regard to many common quality indicators but provide a sound basis for future assessment.

Water quality accounts are generally constructed for a particular sector. For example, the water quality standards for domestic use are more stringent than those for industrial purposes. South Africa uses four categories for water use: domestic, industrial, agricultural, and recreational. Once quality classes have been established for the relevant parameters (for example, BOD, suspended solids, and pH), they are incorporated into an accounting structure similar to an asset account

South Africa has followed the French (IFEN) method for assigning quality to inland waters. This method has been used successfully in the UK and Slovenia. Quality measurements are taken at point locations. The data is assigned to a quantity that represents the total flow of water at that point. The EuroWaterNet agency uses the Standard River Unit of 1 km.m^3 (cubic metre)/s. Using this method, stretches of inland water of different size with different flow rates can be aggregated.

Measurement of water quality involves the assessment of many different parameters. In South Africa, there is a well-established network to measure the inorganic aspects of water quality such as salinity. There are also developing networks to measure eutrophication and microbiological quality of inland water (although the extension of these networks is hindered by the cost of sampling and analysis). Plans are also under way to develop a monitoring system for heavy metal and organic pollutants (measurement of radioactive contamination is only performed in areas where there are known problems (Statistics South Africa 2000). In general, most of the water in South Africa falls into the second quality class (in terms of chemical indicators). There are, however, concerns in some areas about faecal pollution from human settlements and high TDS (total dissolved solid) due to the dry climate in the interior of the country.

It is clear from this review that different countries take different routes to account for fresh water. Some of the countries do only physical accounting but they do acknowledge the need for monetary accounts in order to have a meaningful impact on sectoral and macro-policies of the changes in the stock and flow of water resources. In most of the cases, availability and type of data determine the choice of methodology employed.

Quantity of groundwater in India

It is certainly true that in many areas of India (including parts of Rajasthan, Haryana, Punjab, and Tamil Nadu), groundwater resources are being used in an unsustainable manner. This is plainly evident from the lowering of the water table, which is particularly obvious when wells run dry and boreholes have to be sunk deeper. This reality is not obvious from most published government figures pertaining to the groundwater assets of the country, as they tend to focus on India's available rechargeable groundwater resources. In part, this is due to the nature of groundwater assets. Precipitation, and hence surface water flow, allows a level of recharge to occur in unconfined aquifers. In other words, groundwater resources are in some sense renewable. This statement comes with caveats: aquifers need to be unconfined (that is, water from the surface is able to percolate through the rock strata to reach the aquifer) and water extraction should not exceed the volume of recharge.

A further factor to consider is the 'invisible' character of groundwater. It is not clear how much water is held in aquifers and it is expensive to fully investigate this complex underground system.

For the purpose of this report, we are concerned with the available groundwater volume, but it is worth mentioning that often a more important concept is the depth to water from the surface. As noted by Moench (2000), overextraction of groundwater and the associated water level decline can affect the sustainability of uses that are dependent on groundwater long before the groundwater itself is exhausted. For example, groundwater flows, which contribute to rivers, are affected when the depth to the water table is lowered. Box 1 gives more information about the complex issues involved in estimating available groundwater resources.

Box 1 Problems in estimating groundwater quantity

- Assessing groundwater volumes is difficult due to methodological problems and the availability of data. This translates into large uncertainties in both the measurement of recharge volumes and the assessment of extraction levels.
- The replenishable groundwater resource is calculated using the 'Water Table' method. Here, the depth to the water table is measured before and after the monsoon. The estimated area of the aquifer multiplied by the increase in water level gives the volume of water replenished. This figure is stated as the groundwater resource of the area.
  Total replenishable volume: 432 BCM (billion cubic metres) per year
  Total volume to a depth of 450 m: 10 812 BCM
- Measuring extraction is complex due to the number of private wells for both agricultural and domestic use. Many proxies are used to give an estimation of extraction. Examples include the area under irrigation and well census figures.

Data transparency

The volume of available groundwater in an area is a politically sensitive issue. Funding for groundwater development is dependent on the percentage of the groundwater being extracted. This leads to great pressure on groundwater professionals to adjust figures to prevent regions from changing category in terms of groundwater development.

Sources Central Ground Water Board (1995) and Central Pollution Control Board (2004 a).

Quality of groundwater in India

In 1994, the CPCB (Central Pollution Control Board) analysed groundwater in 22 regions that had been identified as 'problem areas' in terms of groundwater quality. The data from these surveys was collated into a comprehensive report, detailing the main areas of concern and giving recommendations for future action. These 22 areas cover a number of states and the quality problems identified fall into many categories. Some of the pollutants arise from natural sources but the overwhelming majority owe their origin to industrial discharge, domestic sewage, and by-products from agricultural activities. Common problems are high total coliform counts, high TDS, pesticide contamination, and the presence of heavy metals and fluoride. Tables 1–3 provide details in this regard.

Groundwater once contaminated is difficult to clean, so water has to be treated once it has been pumped from the wells. Many of the purification procedures are very expensive, especially for the more toxic contaminants such as heavy metals (Appendix 1).

Estimation of groundwater quality

Concern over groundwater pollution has risen dramatically during the past few years. It was once assumed that these water supplies were protected from pollution by virtue of being underground. However, it has since been recognized that pollutants can seep into aquifers from point sources such as leaking landfill sites and from more diffused sources such as agricultural run-off. In addition, some naturally occurring pollutants have been concentrated due to overextraction. Groundwater pollution is potentially very serious as many communities rely solely on these water supplies especially in the dry season. Parameters of pressing concern are the biological contaminants as measured by total coliforms; pesticides such as DDT (dichloro–diphenyl–trichloroethane) and aldrin; heavy metals such as mercury, lead, and arsenic; metals such as iron and manganese; halogens such as fluorine; and nitrates. Salinity levels are also increasing due to problems such as sea-water ingress and returns of irrigation water, leading to a reduction in water quality.

Table 1

Water pollution source in states

State	*Area*	*Pollution source and industry type*
Andhra Pradesh	Visakhapatnam	Iron and zinc processing, petro-chemicals, fertilizer, untreated municipal sewage
Andhra Pradesh	Patancheru–Bolaram	Leather manufacture, slaughter houses, pesticide, pharmaceuticals
Assam	Digboi	Oil refinery, municipal sewage
Bihar	Dhanbad	Coal mining and washing, steel, fertilizer, cement plant, coke plant, explosives
Delhi	Najafgarh	Agricultural run-off, domestic sewage, insecticide, electro-plating, caustic soda, dumping of solid waste
Himachal Pradesh	Kala Amb	Engineering and pharmaceutical industries, agricultural run-off
Himachal Pradesh	Parwano	Electro-plating, pharmaceuticals, pesticide, sewage, agricultural run-off
Karnataka	Bhadravathi	Paper, iron and steel, municipal sewage, agricultural run-off
Kerala	Greater Cochin	Sea-water intrusion, chemical industries, insecticide production, refinery, gypsum dumps
Maharashtra	Chembur	Petroleum refinery, petro-chemicals, fertilizer, thermal power plant, sea-water ingress, municipal sewage
Madhya Pradesh	Ratlam–Nagda	Distilleries, dye intermediates, pharmaceutical intermediates, agricultural run-off
Madhya Pradesh	Korba	Power plants, aluminium industry, explosives, coal mining, municipal sewage
Orissa	Angul–Talcher	Coal mining, power plants, fertilizer production, chemicals, smelting, heavy water
Punjab	Govindgarh	Electro-plating, steel, metal processing, wood industries
Rajasthan	Jodhpur	Agricultural run-off, textiles, engineering, dye, plastics and oil
Rajasthan	Pali	Domestic effluent, agricultural run-off, textile industries
Tamil Nadu	Manali	Chemicals, fertilizers and petro-chemicals, sea-water ingress
Tamil Nadu	North Arcot	Tanneries, match industry, dying units, municipal sewage
Uttar Pradesh	Singrauli	Aluminium, carbon, pesticides, chemicals, coal mining, power plants
West Bengal	Durgapur	Metal and coal-handling industries
West Bengal	Howrah	Foundries, electro-plating

Source CPCB (1995)

The quality data has been compiled by using the mean values over the specified time period for each sample location within the target region. These are normally tube wells and dug wells, and the water supplied is used for a range of purposes including drinking, bathing, and irrigation. These values have been averaged to give a mean value for the area as a whole. This approach is limited because adjacent groundwater wells can have vastly different levels of contamination due to complexities in the aquifer system, hydro-geologic setting, and properties of the contaminant. Tables 2–4 show the breakdown of this information by problem area, contaminant, and relation to the acceptable limits while Tables 5–10 provide the information in the sequence by state.

Table 2

Groundwater volumes in problem areas

State	*Area*	*Study area* (km^2)	*State area* (km^2)	*Groundwater in the state* (MCM)	*Total Volume in study area* (MCM)
Andhra Pradesh	Visakhapatnam	93.44	275 069	35 290	11.99
Andhra Pradesh	Patancheru–Bolaram	70	275 069	35 290	8.98
Assam	Digboi (Tinsukia)	3 790	78 438	24 720	1 194.43
Bihar	Dhanbad	2 885	94 163	33 520	1 027.00
Delhi	Najafgarh	832	1 483	290	162.70
Himachal Pradesh	Kala Amb (Sirmaur)	2 825	55 673	370	18.77
Himachal Pradesh	Parwano (Solan)	1 936	55 673	370	12.87
Karnataka	Bhadravathi	39.95	191 791	16 900	3.52
Kerala	Greater Cochin	187	38 863	7 900	38.01
Maharashtra	Chembur	20	307 713	37 870	2.46
Madhya Pradesh	Ratlam–Nagda	4 861	308 000	50 890	803.17
Madhya Pradesh	Korba,	284.56	308 000	50 890	47.02
Orissa	Angul–Talcher	2 511.32	155 707	20 000	322.57
Punjab	Govindgarh	7.04	50 362	18 660	2.61
Rajasthan	Jodhpur	40	342 239	12 710	1.49
Rajasthan	Pali	3 087.96	342 239	12 710	114.68
Tamil Nadu	Manali (Chengai MCR District)	7 863	130 058	26 390	1 595.48
Tamil Nadu	North Arcot	5 887	130 058	26 390	1 194.53
Uttar Pradesh	Singrauli (Mirzapur)	4 952.5	238 566	72 000	1 494.68
West Bengal	Durgapur	154	88 752	23 090	40.07
West Bengal	Howrah	1 474	88 752	23 090	383.48

MCM – million cubic metres
Source CPCB (1995)

Table 2 shows the groundwater volume for each study area. These were calculated by using the ratio of study area to state area and multiplying by the total volume of groundwater in the state. In some cases, where the size of the study area was unknown, district area was used as the closest approximation.

The nature of pollutants differ across states, and different states have different types of problems; for example, Punjab faces the presence of lead in its water while the data from Madhya Pradesh shows manganese, and Karnataka is struggling with the presence of zinc. The concentration of heavy metal pollution is given in Table 3. Table 4 shows the deviation of metal contaminant levels from the acceptable limit given by the CPCB. Pollutants showing positive values reflect pollution of the groundwater.

Other criteria of describing the quality of groundwater have been compiled, and their deviation from nationally acceptable limit has been calculated. The main criteria and chemical parameters are TDS, N, Cl (chlorine), coliforms, and pesticides (aldrin, DDT) (Table 5). Tables 6 and 7 are self-explanatory as far as the spread and types of pollutants across the states are concerned. Problems seem to be pervasive and alarming.

In addition to the areas listed in the CPCB report, water salinity has been observed as a major problem in some states (Box 2).

Box 2 A summary of the salinity problem in India

- Saline groundwater, a feature of both inland and coastal states, is the result of a variety of factors. These include residue from irrigation waters, industrial pollution, and reversal of the hydraulic gradient in aquifers leading to sea-water ingress. The increasing levels of salinity have wide–ranging impacts on agriculture and health.
- It is difficult to assess the extent of saline groundwater because it can occur in particular horizons or be pervasive across entire aquifer systems. The extent of the problem is controlled by the characteristics of the aquifer and the local geology.
- The use of saline water for irrigation affects crop yield and quality, and the characteristics of the soil. The effect on crop yield can, however, be mitigated by cultivating species that are less sensitive to saline conditions.
- The high sodium levels associated with increased salinity affect the behaviour of clay particles in the soil, reducing drainage and irrigation efficiency.

Coastal salinity ingress

Many coastal regions are supplied with fresh water by aquifers that are in contact with the sea. These coastal aquifers are a vital source of fresh water but are under threat as overextraction causes the hydraulic balance between fresh and salt water to be reversed. This can lead to the interface between the two waters moving landwards producing a salinity ingress. As little as 2% contamination by sea water can render freshwater sources non-potable (CPCB 2003).

- Measurement of either total dissolved solid content or electrical conductivity gives an indication of the salinity level. Here the groundwater has been assessed using electrical conductivity.
- Acceptable limits of conductivity vary between regulatory bodies, particularly in terms of water for irrigation. This is due to the varying sensitivities of crops to saline water and so in effect a range of waters can be used. The CPCB (Central Pollution Control Board) gives a value of less than 2 dS (deci-Siemens)/m (or 2000 µmhos/cm) for raw waters used for organized community water supplies and 2.25 dS/m as an acceptable limit for irrigation waters. However, an electrical conductivity of 4 dS/m is acceptable in special planned cases where the limits can be relaxed.
- Many states have chosen to define the groundwater as saline if the value of electrical conductivity exceeds 3.46 dS/m.

Although there are many different water quality criteria to be considered at any one time, it only requires one parameter to exceed acceptable limits for the water to be deemed polluted.

Estimating surface water volume in India

Assessing the amount of available surface water by state has proved far more difficult than estimating groundwater volume. Surface water data is published in terms of river basins and these invariably do not match state boundaries. In addition, the total amount of surface water available for each state is a classified information, not generally available.

In order to provide estimates of available surface water for each state, a combination of approaches has been adopted. While compiling this table, it has been assumed that the total amount of surface water available each year does

Table 3

Metal and heavy metal contamination in groundwater

State	*Area*	*Lead* (µg/l)	*Iron* (µg/l)	*Mercury* (µg/l)	*Cadmium* (µg/l)	*Chromium* (µg/l)	*Manganese* (µg/l)	*Zinc* (µg/l)
Andhra Pradesh	Visakhapatnam	35.76	NA	NA	NA	NA	NA	NA
Andhra Pradesh	Patancheru–Bolaram	63.45	277.57	NA	NA	NA	146.27	NA
Assam	Digboi	16.87	3 068.25	NA	NA	NA	808.38	NA
Bihar	Dhanbad	31.64	759.60	3.14	NA	NA	126.56	NA
Delhi	Najafgarh	NA	872.70	NA	NA	25.5	NA	NA
Himachal Pradesh	Kala Amb	83.25	NA	NA	21.75	NA	NA	NA
Himachal Pradesh	Parwano	NA	1 084.70	NA	17.88	NA	95.20	NA
Karnataka	Bhadravathi	56.88	3 394.00	NA	0.25	NA	557.44	417.82
Kerala	Greater Cochin	NA	121.40	NA	NA	NA	NA	NA
Maharashtra	Chembur	NA	NA	NA	NA	NA	NA	NA
Madhya Pradesh	Ratlam–Nagda	406.7	NA	NA	NA	NA	18 360.00	673
Madhya Pradesh	Korba	NA	3 500.00	NA	NA	60	NA	NA
Orissa	Angul–Talcher	NA	NA	NA	NA	NA	NA	NA
Punjab	Govindgarh	207.2	NA	NA	16.4	NA	NA	NA
Rajasthan	Jodhpur	NA	NA	NA	NA	NA	NA	NA
Rajasthan	Pali	200	NA	NA	NA	NA	NA	400
Tamil Nadu	Manali	NA	1 629.00	NA	NA	NA	943.83	NA
Tamil Nadu	North Arcot	NA	150.00	NA	NA	330	210.00	NA
Uttar Pradesh	Singrauli	NA	2 530.00	NA	NA	70	NA	NA
West Bengal	Durgapur	29.64	349.80	1.97	NA	NA	503.94	NA
West Bengal	Howrah	79.44	1 166.20	2.921	NA	NA	606.74	NA

Accepable limits: lead – 50 µg/l; iron – 300 µg/l; mercury – 1 µg/l; cadmium – 5 µg/l; chromium – 100 µg/l; manganese – 100 µg/l; zinc – 300 µg/l; NA – not available

Source CPCB (1995)

Table 4

Deviation from acceptable limits

State	*Area*	*Lead* (µg/l)	*Iron* (µg/l)	*Mercury* (µg/l)	*Cadmium* (µg/l)	*Chromium* (µg/l)	*Manganese* (µg/l)	*Zinc* (µg/l)
Andhra Pradesh	Visakhapatnam	-14.24	NA	NA	NA	NA	NA	NA
Andhra Pradesh	Patancheru-Bolaram	13.46	-22.42	NA	NA	NA	46.27	NA
Assam	Digboi	-33.13	2 768.3	NA	NA	NA	708.38	NA
Bihar	Dhanbad	-18.36	459.6	2.14	NA	NA	26.56	NA
Delhi	Najafgarh	NA	572.7	NA	NA	-74.5	NA	NA
Himachal Pradesh	Kala Amb	33.25	NA	NA	16.75	NA	NA	NA
Himachal Pradesh	Parwano	NA	784.7	NA	12.88	NA	-4.80	NA
Karnataka	Bhadravathi	6.88	3 094	NA	-4.75	NA	457.44	117.82
Kerala	Greater Cochin	NA	-178.6	NA	NA	NA	NA	NA
Maharashtra	Chembur	NA	NA	NA	NA	NA	NA	NA
Madhya Pradesh	Ratlam-Nagda	356.70	NA	NA	NA	NA	18 260.00	373
Madhya Pradesh	Korba,	NA	3200	NA	NA	-40	NA	NA
Orissa	Angul-Talcher	NA	NA	NA	NA	NA	NA	NA
Punjab	Govindgarh	157.20	NA	NA	11.4	NA	NA	NA
Rajasthan	Jodhpur	NA	NA	NA	NA	NA	NA	NA
Rajasthan	Pali	150.00	NA	NA	NA	NA	NA	100
Tamil Nadu	Manali	NA	1 329	NA	NA	NA	843.83	NA
Tamil Nadu	North Arcot	NA	-150	NA	NA	230	110.00	NA
Uttar Pradesh	Singrauli	NA	2 230	NA	NA	-30	NA	NA
West Bengal	Durgapur	-20.36	49.8	0.97	NA	NA	403.94	NA
West Bengal	Howrah	29.44	866.2	1.921	NA	NA	506.74	NA

Accepable limits: lead – 50 µg/l; iron – 300 µg/l; mercury – 1 µg/l; cadmium – 5 µg/l; chromium – 100 µg/l; manganese – 100 µg/l; zinc – 300 µg/l; NA – not applicable

Source Compiled by authors

Table 5

Chemical parameters of groundwater from problem areas

State	*Area*	*Total dissolved solid* (mg/l)	*Fluoride* (mg/l)	*Nitrate* (mg/l)	*Chloride* (mg/l)	*Sulphate* (mg/l)	*Boron* (mg/l)	*Phenol* (mg/l)	*Calcium* (mg/l)	*Magnesium* (mg/l)	*Cyanide* (mg/l)
Andhra Pradesh	Visakhapatnam	881.71	1.13	27.66	NA	NA	NA	NA	NA	NA	NA
Andhra Pradesh	Patancheru–Bolaram	850.8	0.941429	65.80	NA	NA	NA	NA	NA	NA	NA
Assam	Digboi	NA	0.275	NA	NA	NA	NA	NA	NA	NA	NA
Bihar	Dhanbad	NA	0.762	18.56	NA	NA	NA	NA	NA	NA	NA
Delhi	Najafgarh	826.56	1.42	36.70	NA	NA	1.44	NA	70.9	NA	NA
Himachal Pradesh	Kala Amb	NA	NA	NA	NA	NA	NA	0.085	NA	NA	NA
Himachal Pradesh	Parwano	NA	NA	NA	NA	NA	1.65	0.056	NA	NA	NA
Karnataka	Bhadravathi	487	NA	NA	NA	NA	NA	NA	NA	NA	NA
Kerala	Greater Cochin	320.86	0.22	16.14	NA	NA	NA	NA	NA	NA	NA
Maharashtra	Chembur	953	1.22	NA	NA	NA	NA	NA	NA	NA	NA
Madhya Pradesh	Ratlam–Nagda	2 599.2	1.6325	NA	594.3	NA	5.9	NA	114.64	80.1	0.305
Madhya Pradesh	Korba	NA	0.4	6.95	NA	NA	1.71	NA	NA	NA	NA
Orissa	Angul–Talcher	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Punjab	Govindgarh	669	NA	NA	NA	NA	NA	0.0083	300.8	46.6	0.0552
Rajasthan	Jodhpur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Rajasthan	Pali	7 065.1	1.18	NA	3 002.67	689.33	NA	NA	NA	NA	NA
Tamil Nadu	Manali	4 549	0.39	50.95	NA	NA	NA	NA	NA	NA	NA
Tamil Nadu	North Arcot	11 319	NA	45.67	NA	NA	NA	NA	NA	NA	NA
Uttar Pradesh	Singrauli	327	56.22	NA	NA	NA	2.22	0.26	57.2	19.23	NA
West Bengal	Durgapur	425	0.43	9.75	NA	NA	NA	NA	NA	NA	NA
West Bengal	Howrah	1 261	NA	9.08	NA	NA	NA	NA	NA	NA	NA

Acceptable limits: total dissolved solid – 500 mg/l; fluoride – 1 mg/l; nitrate – 45 mg/l; chloride – 250 mg/l; sulphate – 250 mg/l; boron – 1 mg/l; phenol – 0.001–0.002 mg/l; calcium – 75 mg/l; magnesium – 30 mg/l; cyanide – 0.01 mg/l; NA – not available

Source CPCB (1995)

Table 6

Concentration of chemical parameters in groundwater and deviation from acceptable limits

State	*Area*	*Total dissolved solid* (mg/l)	*Fluoride* (mg/l)	*Nitrate* (mg/l)	*Chloride* (mg/l)	*Sulphate* (mg/l)	*Boron* (mg/l)	*Phenol* (mg/l)	*Calcium* (mg/l)	*Magnesium* (mg/l)	*Cyanide* (mg/l)
Andhra Pradesh	Visakhapatnam	381.71	0.13	-17.34	NA	NA	NA	NA	NA	NA	NA
Andhra Pradesh	Patancheru-Bolaram	350.80	-0.06	20.80	NA	NA	NA	NA	NA	NA	NA
Assam	Digboi	NA	-0.73	NA	NA	NA	NA	NA	NA	NA	NA
Bihar	Dhanbad	NA	-0.24	-26.44	NA	NA	NA	NA	NA	NA	NA
Delhi	Najafgarh	326.56	0.42	-8.30	NA	NA	0.44	NA	-4.1	NA	NA
Himachal Pradesh	Kala Amb	NA	NA	NA	NA	NA	NA	0.083	NA	NA	NA
Himachal Pradesh	Parwano	NA	NA	NA	NA	NA	0.65	0.054	NA	NA	NA
Karnataka	Bhadravathi	-13.00	NA	NA	NA	NA	NA	NA	NA	NA	NA
Kerala	Greater Cochin	-179.14	-0.78	-28.86	NA	NA	NA	NA	NA	NA	NA
Maharashtra	Chembur	453.00	0.22	NA	NA	NA	NA	NA	NA	NA	NA
Madhya Pradesh	Ratlam-Nagda	2 099.20	0.63	NA	344.30	NA	4.9	NA	39.64	50.1	0.295
Madhya Pradesh	Korba	NA	-0.60	-38.05	NA	NA	0.71	NA	NA	NA	NA
Orissa	Angul-Talcher	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Punjab	Govindgarh	169.00	NA	NA	NA	NA	NA	0.0063	225.8	16.6	0.0452
Rajasthan	Jodhpur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Rajasthan	Pali	6 565.17	0.18	NA	2 752.67	439.33	NA	NA	NA	NA	NA
Tamil Nadu	Manali	4 049.33	-0.61	5.95	NA	NA	NA	NA	NA	NA	NA
Tamil Nadu	North Arcot	10 819.33	NA	0.67	NA	NA	NA	NA	NA	NA	NA
Uttar Pradesh	Singrauli	-173.00	55.22	NA	NA	NA	1.22	0.258	-17.83	-10.8	NA
West Bengal	Durgapur	-75.00	-0.57	-35.25	NA	NA	NA	NA	NA	NA	NA
West Bengal	Howrah	761.00	NA	-35.92	NA	NA	NA	NA	NA	NA	NA

Acceptable limits: total dissolved solid – 500 mg/l; fluoride – 1 mg/l; nitrate – 45 mg/l; chloride – 250 mg/l; sulphate – 250 mg/l; boron – 1 mg/l; phenol – 0.001–0.002 mg/l; calcium – 75 mg/l; magnesium – 30 mg/l; cyanide – 0.01 mg/l; NA – not applicable

Source Compiled by authors

Table 7

Coliform and pesticide concentration in groundwater

State	*Area*	*Total coliforms* (MPN/100 ml or TVC*10^3)	*Aldrin* (ng/l)	*DDT* (ng/l)
Andhra Pradesh	Visakhapatnam	604.43	NA	NA
Andhra Pradesh	Patancheru–Bolaram	101.29	430.86	250.14
Assam	Digboi	98.5	NA	NA
Bihar	Dhanbad	358.4	284.2	2 840
Delhi	Najafgarh	30.31	NA	NA
Himachal Pradesh	Kala Amb	NA	0.054	NA
Himachal Pradesh	Parwano	NA	NA	NA
Karnataka	Bhadravathi	40.33	NA	11 600.08
Kerala	Greater Cochin	171.29	NA	NA
Maharashtra	Chembur	1 568.91	393	154
Madhya Pradesh	Ratlam–Nagda	535	303.3	2 341.52
Madhya Pradesh	Korba	69.11	5.76	415.06
Orissa	Angul–Talcher	NA	NA	NA
Punjab	Govindgarh	NA	NA	NA
Rajasthan	Jodhpur	NA	NA	NA
Rajasthan	Pali	NA	NA	NA
Tamil Nadu	Manali	14 590.67	NA	NA
Tamil Nadu	North Arcot	10 997	NA	NA
Uttar Pradesh	Singrauli	54.84	91.16	217.61
West Bengal	Durgapur	970.6	62	4 405.8
West Bengal	Howrah	150.2	90	4 800.2

Acceptable limit: total coliforms – <10 MPN (most probable number)/100 ml (or 10 000); aldrin – absent; DDT – absent; NA – not available

Source CPCB (1995)

Table 8

Deviation from acceptable limit

State	*Area*	*Total coliforms* (MPN/100 ml or TVC*10^3)	*Aldrin* (ng/l)	*DDT* (ng/l)
Andhra Pradesh	Visakhapatnam	594.43	NA	NA
Andhra Pradesh	Patancheru–Bolaram	91.29	430.86	250.14
Assam	Digboi	88.50	NA	NA
Bihar	Dhanbad	348.40*	284.20	2 840.00
Delhi	Najafgarh	20.31	NA	NA
Himachal Pradesh	Kala Amb	NA	0.05	NA
Himachal Pradesh	Parwano	NA	NA	NA
Karnataka	Bhadravathi	30.33	NA	11 600.08
Kerala	Greater Cochin	161.29	NA	NA
Maharashtra	Chembur	1 558.91	393	154
Madhya Pradesh	Ratlam–Nagda	525.00	303.3	2 341.52
Madhya Pradesh	Korba	59.11	5.76	415.06
Orissa	Angul–Talcher	NA	NA	NA
Punjab	Govindgarh	NA	NA	NA
Rajasthan	Jodhpur	NA	NA	NA
Rajasthan	Pali	NA	NA	NA
Tamil Nadu	Manali	14 580.67	NA	NA
Tamil Nadu	North Arcot	10 987.00	NA	NA
Uttar Pradesh	Singrauli	44.84	91.16	217.61
West Bengal	Durgapur	960.60*	62.00	4 405.80
West Bengal	Howrah	150.20*	90.00	4 800.20

Acceptable limit: total coliforms – <10 MPN (most probable number)/100 ml (or TVC [total variable count]* of 10 000); aldrin – absent; DDT – absent; NA – not applicable

Source Compiled by authors

Table 9

River length and volume (by state)

River 1	*State* 2	*Length* (km) 3	*Total length* (km) 4	*Utilizable surface water* (km^3 /year) 5	*Volume* (km^3) 3/4*5
Godavari	Andhra Pradesh	771	1 465	76.3	40.16
Krishna	Andhra Pradesh	386	1 401	58	15.98
Muneru	Andhra Pradesh	122	235	13.11	6.81
Manjeera	Andhra Pradesh	255	686	13.11	4.87
Musi	Andhra Pradesh	112	265	13.11	5.54
Penner	Andhra Pradesh	536	597	6.86	6.16
Tungbhadra	Andhra Pradesh	375	531	13.11	9.26
Brahmaputra	Assam	698	916	24	18.29
Dhansari	Assam	100	354	24	6.78
Gandak	Bihar	300	630	250	119.05
Ganga	Bihar	500	2 525	250	49.50
Ghaghara	Bihar	100	1 080	250	23.15
Sone	Bihar	226	881	250	64.13
Hasdev	Chhattisgarh	233	233	13.11	13.11
Kharoon	Chhattisgarh	220	220	13.11	13.11
Mahanadi	Chhattisgarh	357	851	49.99	20.97
Seonath	Chhattisgarh	383	383	13.11	13.11
Yamuna	Delhi	48	1 376	250	8.72
Mandovi	Goa	78	78	36.28	36.28
Zuari	Goa	56	56	36.28	36.28
Damanganga	Gujarat	30	131	14.98	3.43
Khari	Gujarat	41	41	14.98	14.98
Mahi	Gujarat	242	583	3.1	1.29
Meshwa	Gujarat	220	247	14.98	13.34
Narmada	Gujarat	178.5	1 312	34.5	4.69
Sabarmati	Gujarat	396	444	1.93	1.72
Shedi	Gujarat	190	190	14.98	14.98
Tapi	Gujarat	214	724	14.5	4.29
Ghaggar	Haryana	163	320	46	23.43
Yamuna	Haryana	164	1 376	250	29.80
Beas	Himachal Pradesh	256	460	46	25.60
Parvati	Himachal Pradesh	110	110	46	46.00
Ravi	Himachal Pradesh	158	720	46	10.09
Satluj	Himachal Pradesh	NA	NA	46	NA
Yamuna	Himachal Pradesh	15	1 376	250	2.73
Subarnarekha	Jharkhand	269	395	6.81	4.64
Bhadra	Karnataka	178	178	13.11	13.11
Bhima	Karnataka	860	860	16.73	16.73
Cauvery	Karnataka	352	800	19	8.36
Ghat Prabha	Karnataka	160	283	16.73	9.46
Kabbani	Karnataka	117	240	16.73	8.16
Krishna	Karnataka	375	1 401	58	15.52
Mal Prabha	Karnataka	230	306	16.73	12.57
Shimsha	Karnataka	221	221	16.73	16.73
Tungbhadra	Karnataka	156	531	13.11	3.85
Achenkoil	Kerala	33	128	16.73	4.31
Bhavani	Kerala	NA	216	16.73	0.00
Chaliyar	Kerala	169	169	16.73	16.73
Kabbani	Kerala	123	240	16.73	8.57

Continued

Table 9 *Continued*

River 1	*State* 2	*Length* (km) 3	*Total length* (km) 4	*Utilizable surface water* (km^3 /year) 5	*Volume* (km^3) 3/4*5
Manimala	Kerala	135	135	16.73	16.73
Pamba	Kerala	176	176	16.73	16.73
Periyar	Kerala	244	244	16.73	16.73
Betwa	Madhya Pradesh	232	590	34.5	13.57
Chambal	Madhya Pradesh	184	664	34.5	9.56
Khan	Madhya Pradesh	NA	NA	34.5	NA
Kshipra	Madhya Pradesh	195	195	34.5	34.50
Mahi	Madhya Pradesh	167	583	3.1	0.89
Mandakini	Madhya Pradesh	NA	NA	NA	NA
Narmada	Madhya Pradesh	1 098.5	1 312	34.5	28.89
Sone	Madhya Pradesh	655	881	250	185.87
Tapi	Madhya Pradesh	255	724	14.5	5.11
Tons	Madhya Pradesh	221	284	34.5	26.85
Wainganga	Madhya Pradesh	466	609	34.5	26.40
Bhima	Maharashtra	725	861	36.28	30.55
Girna	Maharashtra	260	260	36.28	36.28
Godavari	Maharashtra	694	1 465	76.3	36.14
Krishna	Maharashtra	640	1 401	58	26.50
Nira	Maharashtra	158	158	36.28	36.28
Patalganga	Maharashtra	NA	NA	36.28	NA
Tapi	Maharashtra	255	724	14.5	5.11
Ulhas	Maharashtra	122	122	36.28	36.28
Wainganga	Maharashtra	258	609	36.28	15.37
Wardha	Maharashtra	483	483	36.28	36.28
Imphal	Manipur	NA	NA	NA	NA
Dhamsiri	Nagaland	NA	354	24	0.00
Baitarni	Orissa	344	355	18.3	17.73
Brahmani	Orissa	541	799	18.3	12.39
I.B	Orissa	170	251	13.11	8.88
Kuakhai	Orissa	NA	NA	13.11	NA
Mahanadi	Orissa	494	851	49.99	29.02
Nagavalli	Orissa	161	256	13.11	8.24
Rushikulya	Orissa	162	162	13.11	13.11
Subarnarekha	Orissa	62	395	6.81	1.07
Beas	Punjab	214	470	46	20.94
Ghaggar	Punjab	102	320	46	14.66
Ravi	Punjab	79	720	46	5.05
Satluj	Punjab	205	NA	46	NA
Chambal	Rajasthan	382	664	34.5	19.85
Mahi	Rajasthan	174	583	3.1	0.93
Testa	Sikkim	309	309	24	24.00
Bhavani	Tamil Nadu	216	216	16.73	16.73
Cauvery	Tamil Nadu	448	800	19	10.64
Tambiraparami	Tamil Nadu	130	130	16.73	16.73
Betwa	Uttar Pradesh	358	590	34.5	20.93
Chambal	Uttar Pradesh	98	664	34.5	5.09
Ganga	Uttar Pradesh	1 505	2 525	250	149.01
Ghaghara	Uttar Pradesh	470	1 080	250	108.80
Gomti	Uttar Pradesh	940	940	250	250.00
Hindon	Uttar Pradesh	256	256	250	250.00
Kalinadi	Uttar Pradesh	NA	NA	NA	NA

Continued

River	*State*	*Length* (km)	*Total length* (km)	*Utilizable surface water* (km^3 /year)	*Volume* (km^3)
1	2	3	4	5	3/4*5
Ramganga	Uttar Pradesh	569	940	250	151.33
Rapti	Uttar Pradesh	198	198	250	250.00
Rihand	Uttar Pradesh	84	224	250	93.75
Sarju	Uttar Pradesh	117	150	250	195.00
Yamuna	Uttar Pradesh	1 149	1 376	250	208.76
Baraker	West Bengal	227	227	250	250.00
Damodar	West Bengal	220	437	250	125.86
Ganga	West Bengal	520	2 525	250	51.49
Roopnarayan	West Bengal	129	129	250	250.00

NA – not available

Source CWC (2004)

not change (this allows comparisons to be made among the states). Initially, this assumption is counter-intuitive because water use is increasing and water shortages are becoming the order of the day. However, it is the fraction of water available for further extraction, which is decreasing (as demand increases) rather than the total available volume each year. Not considering the years in which there are droughts, the amount of water theoretically available from precipitation and surface water run-off remain on average constant. Of course, there are complicating factors. For example, if an upstream state diverts more water for use within that state, it can reduce the amount available for downstream states. It is not possible to adjust the results for this type of change in water supply given the limited data available.

Surface water flows into the rivers (as measured by discharge) and is stored in lakes, reservoirs and dams. Groundwater flows can also contribute to surface run-off, and in this respect there may be some double counting of available water. Data regarding the storage capacity in each state is available for large and medium-sized projects. This information has been incorporated, where appropriate, into the table of state volumes.

Many state governments detail the surface water resources of the state on official websites. This quantity of water is often referred to as total surface water. In these cases, the amount of water available in storage has not been added to the total volume. Otherwise, the total surface run-off is given and so the storage value is assumed to be in addition to this quantity. Further, surface water data has been taken from independent estimates, for example, from World Bank reports or other NGO (non-governmental organization) sources. Again, if the volume stated is referred to as a total, then the storage volume for the state in question has not been added to this quantity.

For states where there is no other source of information, simple approximations have been made using discharge data for specific rivers. In many of the north-eastern states for example, there is information on the catchment area of each river in the state, the proportion of the catchment

Table 10

Water quality (by river and state)

River	State	1993					2003					1993–2003				
		Conductivity (µmhos/cm)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100 ml)	*Nitrates* (mg/l)	*Conductivity* (µmhos/cm)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100 ml)	*Nitrates* (mg/l)	*Conductivity* (µmhos/cm)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100 ml)	*Nitrates* (mg/l)
Godavari	Andhra Pradesh	9.5	2.27	9.1	N A	0.42	275	5.2	5	3 198	NA	265.5	2.93	-4.1	3 198	-0.42
Krishna	Andhra Pradesh	346	1.85	9.1	7.3	0.5	2 864	1.96	31	9 617	NA	2 518	0.11	21.9	9 609.7	-0.5
Maner	Andhra Pradesh	323	1.8	6.7	N A	0.58	436	2.45	10.5	149	NA	113	0.65	3.8	149	-0.58
Manjeera	Andhra Pradesh	180	2.3	8.1	N A	0.927	365	2.7	16	32 192	NA	185	0.4	7.9	32 192	-0.927
Musi	Andhra Pradesh	775	7.8	27.6	N A	4.5	1 488	11.65	94.2	892.5	3.7	713	3.85	66.6	892.5	-0.8
Penner	Andhra Pradesh	801	4.9	24	N A	1.3	774.5	2.75	15.5	781	0.935	-26.5	-2.15	-8.5	781	-0.365
Tungbhadra	Andhra Pradesh	595	2	7.1	N A	2.8	630	2.15	13.4	NA	NA	35	0.15	6.3	0	-2.8
Brahmaputra	Assam	15	1	9.35	8.46	0.23	222	1	13.08	571 565	NA	207	0	3.73	571 556.54	-0.23
Dhansari	Assam	1.4	12.4	9.22	16	NA	173	1.5	9.6	56 460	NA	171.6	-10.9	0.38	56 444	0
Gandak	Bihar	3	1.3	19.6	8.33	1.81	384	1.2	19	1 138	NA	381	-0.1	-0.6	1 129.67	-1.81
Ganga	Bihar	4.25	1.02	16.32	7.87	1.68	374	1.67	16.1	3 208	NA	369.75	0.65	-0.22	3 200.13	-1.68
Ghaghara	Bihar	3	1.9	22	6.22	1.734	318	1.4	19.5	2 013	NA	315	-0.5	-2.5	2 006.78	-1.734
Sone	Bihar	2	0.6	10.8	7.95	1.754	191	1.4	18.7	2 633	NA	189	0.8	7.9	2 625.05	-1.754
Hasdev	Chhattisgarh	11	5.3	66.45	4.2	0.95	NA	2.1	26	290	2	-11	-3.2	-40.45	285.8	1.05
Kharoon	Chhattisgarh	1	1.6	19.3	5.79	0.4	239	1.4	22.8	37	0.242	238	-0.2	3.5	31.21	-0.158
Mahanadi	Chhattisgarh	8.3	3.2	14	4.59	0.82	204	1.8	30.35	66.33	0.27	195.7	-1.4	16.35	61.74	-0.55
Seonath	Chhattisgarh	1	1.8	27.6	5.85	0.495	310	1.95	26.4	336	0.26	309	0.15	-1.2	330.15	-0.235
Yamuna	Delhi	557	2.8	25.7	11	NA	653.5	17.8	58	85 796 668.5	NA	96.5	15	32.3	85 796 657.5	0
Mandovi	Goa	4.8	2.2	5.5	4.66	0.14	36 515	2.8	11	155	NA	36 510.2	0.6	5.5	150.34	-0.14
Zuari	Goa	4.6	2.6	5.7	4.7	0.17	24 318	2.3	11	163	NA	24 313.4	-0.3	5.3	158.3	-0.17
Damanganga	Gujarat	22	1.4	16.1	4	0.306	5 755	2.85	42	60.17	10.5	5 733	1.45	25.9	56.17	10.194
Khari	Gujarat	2 116	416	1 664	1.02	1.709	21 082	958.8	3 662.4	12 783 333	NA	18 966	542.8	1 998.4	12 783 331.98	-1.709
Mahi	Gujarat	152	1.9	13.9	7.6	0.06	281	1.14	13	45	NA	129	-0.76	-0.9	37.4	-0.06
Meshwa	Gujarat	37	2.2	18.1	11.4	0.516	402	1.9	8	7 508	NA	365	-0.3	-10.1	7 496.6	-0.516
Narmada	Gujarat	29	3	16	6.7	0.45	268	1.2	16.75	68.75	NA	239	-1.8	0.75	62.05	-0.45
Sabarmati	Gujarat	173	41	108	11	0.53	1 208	40	277	375 003.33	NA	1 035	-1	169	374 992.33	-0.53
Shedi	Gujarat	74	3	24.8	11.64	0.769	1 241	20.6	101.3	79 395	NA	1 167	17.6	76.5	79 383.36	-0.769
Tapi	Gujarat	33	3.3	22	8.5	0.24	337	1.93	3	574	0.3	304	-1.37	-19	565.5	0.06
Ghaggar	Haryana	292	9.6	31.3	4	0.4	844	9.3	78	NA	NA	552	-0.3	46.7	-4	-0.4
Yamuna	Haryana	311	1.3	14.6	2.4	NA	561.8	10.8	37.68	44 852 752.4	NA	250.8	9.5	23.08	44 852 750	0
Bean	Himachal Pradesh	15.1	0.47	4.2	3.4	0.44	209	1.36	3.7	935	NA	193.9	0.89	-0.5	931.6	-0.44
Parvati	Himachal Pradesh	7	0.2	3	3.2	0.12	189	0.7	8	592	NA	182	0.5	5	588.8	-0.12
Ravi	Himachal Pradesh	15.5	0.4	6.4	3.95	0.2	192	0.75	2.5	40	NA	176.5	0.35	-3.9	36.05	-0.2
Satluj	Himachal Pradesh	27.6	1.4	5.83	3.51	0.119	262	0.37	7.71	499	NA	234.4	-1.03	1.88	495.49	-0.119
Yamuna	Himachal Pradesh	N A	N A	N A	N A	NA	1 045	3.4	42	137.5	NA	1 045	3.4	42	137.5	0
Jhelum	Jammu and Kashmir	215	N A	N A	N A	2.66	N A	1.2	18	114	NA	-215	1.2	18	114	-2.66

Continued

		1993					2003					1993–2003				
River	State	Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)
Subarnarekha	Jharkhand	150	2.9	6.3	8.5	N A	209	1.87	31.75	1 042	NA	59	-1.03	25.45	1 033.5	0
Bhadra	Karnataka	29	4.3	38	6.7	0.26	271	3.16	N A	1 552	0.19	242	-1.14	-38	1 545.3	-0.07
Bhima	Karnataka	81	1.4	45	7.3	0.4	487	1.6	22.66	6 979	0.26	406	0.2	-22.34	6 971.7	-0.14
Cauvery	Karnataka	26	1	24.26	7.38	0.15	256	1.06	21.6	2 185	0.338	230	0.06	-2.66	2 177.62	0.188
Ghat Prabha	Karnataka	30	1.65	49.4	7.3	0.3	525	1.75	71.7	1 019	NA	495	0.1	22.3	1 011.7	-0.3
Kabbani	Karnataka	25	1.1	27	6.8	N A	287	1.1	22	1 046	0.195	262	0	-5	1 039.2	0.195
Krishna	Karnataka	46	1.2	42.3	7.3	0.16	317	1.65	22.8	2 967	0.21	271	0.45	-19.5	2 959.7	0.05
Mal Prabha	Karnataka	44	1.4	52	7.3	0.47	447	1.46	27.16	1 406	NA	403	0.06	-24.84	1 398.7	-0.47
Shimsha	Karnataka	37	7	31	7.38	0.158	587	1.2	23	2 091	0.495	550	-5.8	-8	2 083.62	0.337
Tungbhadra	Karnataka	41	1.3	23.6	7.3	0.29	189	2.6	38	1 552	NA	148	1.3	14.4	1 544.7	-0.29
Achenkoil	Kerala	5.5	0.5	7.5	7.21	0.38	66	1.9	25.6	5 550	0.35	60.5	1.4	18.1	5 542.79	-0.03
Bhavani	Kerala	11	0.4	6.7	7.72	0.5	109	0.3	3.2	875	0.19	98	-0.1	-3.5	867.28	-0.31
Chaliyar	Kerala	210	0.45	8	7.69	0.32	2 069	0.45	8.4	1 450	NA	1 859	0	0.4	1 442.31	-0.32
Kabbani	Kerala	6	0.4	4.7	7	N A	81	0.6	3.2	825	0.15	75	0.2	-1.5	818	0.15
Manimala	Kerala	4.5	0.4	6.8	7.6	0.47	58	0.7	14.4	3 062	0.348	53.5	0.3	7.6	3 054.4	-0.122
Pamba	Kerala	5.5	0.7	8.1	7.3	0.33	1 117	1.1	20.8	14 866	0.93	1 111.5	0.4	12.7	14 858.7	0.6
Periyar	Kerala	9.8	5.3	8.3	7.3	0.5	334	1.4	6.4	390	0.02	324.2	-3.9	-1.9	382.7	-0.48
Betwa	Madhya Pradesh	N A	N A	N A	N A	N A	284	2.1	26	924	NA	284	2.1	26	924	0
Chambal	Madhya Pradesh	172	8.5	60	6.01	0.73	1 035	2.77	11.92	636 198	0.2	863	-5.73	-48.08	636 191.99	-0.53
Khan	Madhya Pradesh	81	47.8	195.3	9.83	N A	1 546	30	N A	1 600	NA	1 465	-17.8	-195.3	1 590.17	0
Kshipra	Madhya Pradesh	77	6.8	62.8	9.875	N A	820	4.9	20	N A	NA	743	-1.9	-42.8	-9.875	0
Mahi	Madhya Pradesh	N A	2.3	30.3	4.91	0.71	N A	N A	25	425	NA	0	-2.3	-5.3	420.09	-0.71
Mandakini	Madhya Pradesh	321	2.8	41.3	4.46	0.23	N A	6	N A	345	NA	-321	3.2	-41.3	340.54	-0.23
Narmada	Madhya Pradesh	105	2.5	22	5.3	0.27	217	1.82	21.4	179	N A	112	-0.68	-0.6	173.7	-0.27
Sone	Madhya Pradesh	326	2.2	44	3.8	0.16	191	1.6	18.7	666	N A	-135	-0.6	-25.3	662.2	-0.16
Tapi	Madhya Pradesh	227	2	24	5.18	0.5	132	1.26	17.33	126.66	N A	-95	-0.74	-6.67	121.48	-0.5
Tons	Madhya Pradesh	337	2.6	32	4.22	0.19	N A	5.95	N A	435.5	N A	-337	3.35	-32	431.28	-0.19
Wainganga	Madhya Pradesh	17	5.2	38.5	5.4	0.05	353.5	2.25	20.5	292	N A	336.5	-2.95	-18	286.6	-0.05
Bhima	Maharashtra	33	5.2	24.85	4.2	0.57	445	16.18	24	278	0.36	412	10.98	-0.85	273.8	-0.21
Girna	Maharashtra	31	5.1	24.5	4.3	0.48	295	6	5	254	N A	264	0.9	-19.5	249.7	-0.48
Godavari	Maharashtra	37.14	4.87	25.14	4.43	0.86	482	8.08	93	278	0.95	444.86	3.21	67.86	273.57	0.09
Krishna	Maharashtra	21	4.8	21.46	4.2	0.66	448	6.3	34	265	0.96	427	1.5	12.54	260.8	0.3
Nira	Maharashtra	41	4.9	56	4.4	0.57	398	6.5	N A	228	0.746	357	1.6	-56	223.6	0.176
Patalganga	Maharashtra	21.5	4.75	26.1	4.3	0.34	121	5.3	24	214	0.5	99.5	0.55	-2.1	209.7	0.16
Tapi	Maharashtra	37	5.3	26	4.2	0.6	467	5.9	4.66	231	0.0655	430	0.6	-21.34	226.8	-0.5345
Ulhas	Maharashtra	24	4.55	22.4	4.2	0.42	128	5.7	32	218	0.47	104	1.15	9.6	213.8	0.05
Wainganga	Maharashtra	18	6.8	24.7	N A	0.92	274	5.8	32	183	0.283	256	-1	7.3	183	-0.637
Wardha	Maharashtra	64	5.6	26	4.43	1.96	377	5.2	N A	173	0.95	313	-0.4	-26	168.57	-1.01
Imphal	Manipur	31.5	2.2	4.6	5.92	0.12	103	2.4	N A	60	N A	71.5	0.2	-4.6	54.08	-0.12
Dhamsiri	Nagaland	N A	N A	N A	N A	N A	226	4.38	N A	N A	N A	226	4.38	0	0	0

Continued

Table 10 *Continued*

River	State	1993 Conductivity (µmhos/cm)	1993 BOD (mg/l)	1993 COD (mg/l)	1993 Total coliforms (MPN/100 ml)	1993 Nitrates (mg/l)	2003 Conductivity (µmhos/cm)	2003 BOD (mg/l)	2003 COD (mg/l)	2003 Total coliforms (MPN/100 ml)	2003 Nitrates (mg/l)	1993–2003 Conductivity (µmhos/cm)	1993–2003 BOD (mg/l)	1993–2003 COD (mg/l)	1993–2003 Total coliforms (MPN/100 ml)	1993–2003 Nitrates (mg/l)
Baitarni	Orissa	26.8	4.36	22.56	5.92	N A	5 642	1.66	N A	4 437	0.08	5 615.2	-2.7	-22.56	4 431.08	0.08
Brahmani	Orissa	30.9	3.54	14.45	6.25	N A	160	17	4.2	3 399	1.41	129.1	13.46	-10.25	3 392.75	1.41
I.B	Orissa	33	4.9	23.4	5.5	N A	147	1.55	N A	3 539	N A	114	-3.35	-23.4	3 533.5	0
Kuakhai	Orissa	26	3.6	14.6	6.15	N A	180	2.25	N A	4 779	N A	154	-1.35	-14.6	4 772.85	0
Mahanadi	Orissa	27	4.1	19	5.8	N A	4 585.5	1.86	24	5 706	N A	4 558.5	-2.24	5	5 700.2	0
Nagavalli	Orissa	N A	N A	N A	N A	N A	431	2.25	N A	7 480	0.404	431	2.25	0	7 480	0.404
Rushikulya	Orissa	77.5	17.8	75	3.24	N A	9 206	1.8	N A	5 150	0.65	9 128.5	-16	-75	5 146.76	0.65
Subarnarekha	Orissa	N A	N A	N A	N A	N A	274	1.7	2 330	N A	0.34	274	1.7	2330	0	0.34
Bean	Punjab	1	7.4	16.7	4.5	1.52	277	2.06	6.22	783	N A	276	-5.34	-10.48	778.5	-1.52
Ghaggar	Punjab	1	20	39	4	N A	474	32	94	3 658	N A	473	12	55	3 654	0
Ravi	Punjab	N A	0.8	1.9	3	0.665	493	12.8	25	2 944	N A	493	12	23.1	2 941	-0.665
Satluj	Punjab	4.4	4.43	7.4	3.85	1.2	387	4.52	12.58	5 076	N A	382.6	0.09	5.18	5 072.15	-1.2
Chambal	Rajasthan	1	2.4	38	6.73	0.48	314.67	1.63	8.17	737	0.13	313.67	-0.77	-29.83	730.27	-0.35
Mahi	Rajasthan	N A	2.4	39.4	7.22	0.359	510	1.7	8.1	914	N A	510	-0.7	-31.3	906.78	-0.359
Testa	Sikkim	N A	N A	NA	N A	N A	278	8.55	N A	199	N A	278	8.55	0	199	0
Bhavani	Tamil Nadu	33	15.27	43.5	11.1	0.5	233	1.6	13.8	1 243	N A	200	-13.67	-29.7	1 231.9	-0.5
Cauvery	Tamil Nadu	57	2.58	16.38	10.5	0.5	2 823	2.13	53.3	1 083	N A	2 766	-0.45	36.92	1 072.5	-0.5
Tambiraparami	Tamil Nadu	N A	N A	N A	N A	N A	333	1.8	21.7	251	0.24	333	1.8	21.7	251	0.24
Betwa	Uttar Pradesh	39	2.2	17.7	12.26	0.54	284	2.1	27	1 100	N A	245	-0.1	9.3	1 087.74	-0.54
Chambal	Uttar Pradesh	416	2.8	15.3	1	0.8	548	2.2	11.9	2 542 583	N A	132	-0.6	-3.4	2 542 582	-0.8
Ganga	Uttar Pradesh	12	2.61	15	8.92	0.4	257	2.91	17.05	21 330	0.846	245	0.3	2.05	21 321.08	0.446
Ghaghara	Uttar Pradesh	31	3.2	8.1	8.43	0.8	351	1.3	21.05	1 120	N A	320	-1.9	12.95	1 111.57	-0.8
Gomti	Uttar Pradesh	54	5.03	19.76	9.52	0.42	N A	2.5	15.5	18 798	1	-54	-2.53	-4.26	18 788.48	0.58
Hindon	Uttar Pradesh	129	58	135	8.2	N A	956	29.866	176	3 335 653.6	6.32	827	-28.134	41	3 335 645.4	6.32
Kalindi	Uttar Pradesh	39	3.9	27.2	12.26	N A	703	34.92	219	163 305 562	17.66	664	31.02	191.8	163 305 549	17.66
Ramganga	Uttar Pradesh	46	3.9	25.7	9.53	N A	446	4.7	N A	11 244	N A	400	0.8	-25.7	11 234.47	0
Rapti	Uttar Pradesh	32	3	7.3	N A	0.73	408	2.2	22.8	128	N A	376	-0.8	15.5	128	-0.73
Rihand	Uttar Pradesh	N A	2.3	13	8.3	0.005	223.5	2	42	2 454	0.007	223.5	-0.3	29	2 445.7	0.002
Sarju	Uttar Pradesh	N A	N A	N A	N A	N A	331	3.3	16	6975	N A	331	3.3	16	6 975	0
Yamuna	Uttar Pradesh	767	6.6	21.35	7.98	2.45	766	6.62	29.12	40 826 494	0.36	-1	0.02	7.77	40 826 486	-2.09
Baraker	West Bengal	159	4.8	23.3	NA	N A	N A	1.2	N A	70 000	N A	-159	-3.6	-23.3	70 000	0
Damodar	West Bengal	2 025	2.42	35.6	11.39	0.01	891	1.83	16.4	252 179.6	0.138	-1 134	-0.59	-19.2	252 168.21	0.128
Ganga	West Bengal	538	1	16.75	11.2	0.22	470	2.43	24.42	340 337	0.18	-68	1.43	7.67	340 325.8	-0.04
Roopnarayam	West Bengal	1 789	1.1	18.2	11.39	0.166	238	1.6	N A	2 383 335	N A	-1 551	0.5	-18.2	2 383 323.6	-0.166

BOD – biochemical oxygen demand; COD – chemical oxygen demand; MPN – most probable number; NA – not applicable

Source Compiled by authors

area that falls within the state, and the river discharge. This information can be used to approximate river discharge by state. This estimate is ideal but in the absence of relevant data, it provides a rough approximation of surface flow in the state. For the remaining states, a similar method has been employed by using the length of the river in each state as compared to the total length and total discharge. Again, this method is severely limited but is useful for a general approximation. In both of these cases, water storage capacity has been considered in addition.

The information provided on water volume by state can only be considered as a guideline to the amount of water available. Unfortunately, the data does not represent the volume at any particular point in time as the data has been taken from different sources for a number of years.

In Table 9, the total length of all the major rivers in India, length of these rivers by state, and utilizable surface water in these rivers are recorded. The proportionate length of river in each state has been multiplied by utilizable surface water in that river to approximate the total volume of water in each river in each state.

Quality of surface water

The quality of surface water is under threat from industrial, agricultural, and domestic waste, and these contaminants are often concentrated in water bodies by overextraction. Additional problems are caused when these pollutants interact with each other or decompose to produce toxic by-products.

New pollutants are frequently introduced into the environment by industrial and domestic activities. These pollutants are not only directly detrimental to human health when consumed in drinking water but also severely affect aquatic ecosystems and the services they provide. Quality issues are compounded when overextraction leads to a reduction in the available water for diluting waste discharge.

Contaminants can be classified into different categories including organic, inorganic, biological, and thermal. It would clearly be unfeasible to monitor every compound that is discharged into water supplies; instead a number of indicator criteria are used. As the water quality accounts must be comparable throughout the country, only the limited number of criteria used in every state can be included in this study. The data needs to be consistent not only spatially but also temporally, further constraining the number of parameters available for use.

The general quality indicators used in this report are total coliforms, BOD, COD, and conductivity. Unfortunately, other essential quality measures such as nitrate levels have only been measured for 2003 and cannot be included in the survey of surface water. Appendices 1–5 give details of the polluted stretches of the rivers, lakes, reservoirs, and tanks in different states of India.

One of the most pressing concerns for India in particular is the high level of bacteria in water, which are the cause of many water-borne diseases. These pollutant levels can be monitored by measuring the load of coliforms in the water. The coliforms themselves do not cause disease but serve as indicators for pathogens that are detrimental to health. These organisms find their way into water from untreated sewage and animal effluent. An acceptable level is 200 colonies per 100 ml, but many Indian water courses far exceed this level. This water, if used for bathing and drinking, can lead to serious illness. There are two methods for assessing the levels of disease-causing bacteria: TVC (total variable count) and MPN (most probable number) methods. Whilst most states use MPN, some have quoted the levels using the TVC method, which makes it difficult to compare data sets.

The level of organic pollution is also very high. The organic matter is processed by bacteria that consume oxygen while breaking down this material. This reduces the dissolved oxygen content of the water, leading to near–anoxic conditions that are poisonous for fish populations and other aquatic organisms. The concentration of organic matter can be assessed by measuring the BOD of the water. Water with a BOD level above 3 mg/l is considered polluted and above 6 mg/l as heavily polluted. Some stretches of the Yamuna river in Delhi have a BOD as high as 58 mg/l. The overall oxygen demand from substances in water can be found by considering at the COD. This measures the demand from every component of the water, which requires oxygen for decomposition. COD is, therefore, always higher than BOD but does not differentiate between biological and inorganic contaminants. It gives a broader indication of the total pollutant load, which BOD alone fails to do. A comparison of BOD and COD can give clues on other compounds in water. For example, very high COD but low BOD can suggest the presence of chemicals that are toxic to bacterial population and may merit further investigation. Finally, the conductivity of the water is measured. This is essentially a measurement of the TDS (Total Dissolved Solids) of the water.

Computation of change in the quality of surface water during 1993–2003

The data on pollutants, especially with regard to conductivity, BOD, COD, total coliforms, and N, for different rivers flowing through the states, has been compared over the period 1993–2003. The data on pollutants has been generated from water samples collected by the CPCB. Different rivers have been considered for the same state. Changes in quality of water, using the suggested parameters, show a decline in the quality of water over the decade. Details are provided in Table 10.

Table 10 shows the actual levels of five parameters of water quality (by river and by state), namely, conductivity, BOD, COD, total coliforms, and nitrates. Changes in these parameters of water quality are recorded from 1993 to 2003 for which data is available. Positive values show deterioration in water quality while negative values show improvement. While conductivity and total coliform levels in the water have worsened, BOD and COD levels have shown improvement in some cases. Overall trends point to a sharp fall in the quality of water over the period 1993–2003.

The use of water in the country has been considered for three dominant purposes: irrigation, drinking, and industry. Water used for each purpose has an acceptable limit usually provided by the CPCB. For 1993, the deviation of pollutants from the acceptable levels and corresponding volume of water have been estimated for each state. The same exercise has been repeated for different uses for 1993 and 2003. Details are given in Tables 11–13.

Likewise, the deviation from the acceptable limit for irrigation has been computed for 2003 (Appendix 6).

The quality standards set for drinking water are, as perhaps one would expect, higher than the water used for irrigation and industry. Our results show that the rate of change of deviation between the measured value and the acceptable limit over the period 1993–2003 has increased across different states, which indicates a decline in water quality. This decline is primarily driven by human activities of various types. Table 11 provides the details of deviation from acceptable limit of drinking water in 1993. Over 1993–2003, the deviations have been given (by river) but they have been aggregated for the states (Appendix 7). In order to aggregate the data by state, the total length of all the major rivers in India, length of these rivers by state, and utilizable surface water in these rivers are recorded. The proportionate length of river in each state has been multiplied by utilizable surface water in that river to get the total volume of water in each river, in each state.

Appendix 8 gives data on the deviation from the acceptable quality limits for water for irrigation purposes over the period 1993–2003 and Appendix 9 gives the data collated by state (by river) for the change of water quality from acceptable limits between 1993 and 2003.

Table 11

Deviation of quality (for water used for drinking purposes) from the acceptable limits in 1993

River	State	Volume (km³)	Acceptable water quality: Conductivity (μmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Acceptable limit: Conductivity (μmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Difference: Conductivity (μmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)
Godavari	Andhra Pradesh	40.16	9.5	2.27	9.1	NA	0.42	2 000	0	0	0	45	-1 990.5	2.27	9.1	0	-44.58
Krishna	Andhra Pradesh	15.98	346	1.85	9.1	7.3	0.5	2 000	0	0	0	45	-1 654	1.85	9.1	7.3	-44.5
Maner	Andhra Pradesh	6.81	323	1.8	6.7	NA	0.58	2 000	0	0	0	45	-1 677	1.8	6.7	0	-44.42
Manjeera	Andhra Pradesh	4.87	180	2.3	8.1	NA	0.927	2 000	0	0	0	45	-1 820	2.3	8.1	0	-44.073
Musi	Andhra Pradesh	5.54	775	7.8	27.6	NA	4.5	2 000	0	0	0	45	-1 225	7.8	27.6	0	-40.5
Penner	Andhra Pradesh	6.16	801	4.9	24	NA	1.3	2 000	0	0	0	45	-1 199	4.9	24	0	-43.7
Tungbhadra	Andhra Pradesh	9.26	595	2	7.1	NA	2.8	2 000	0	0	0	45	-1 405	2	7.1	0	-42.2
Brahmaputra	Assam	18.29	15	1	9.35	8.46	0.23	2 000	0	0	0	45	-1 985	1	9.35	8.46	-44.77
Dhansari	Assam	6.78	1.4	12.4	9.22	16	NA	2 000	0	0	0	45	-1 998.6	12.4	9.22	16	-45.0
Gandak	Bihar	119.05	3	1.3	19.6	8.33	1.81	2 000	0	0	0	45	-1 997	1.3	19.6	8.33	-43.19
Ganga	Bihar	49.50	4.25	1.02	16.32	7.87	1.68	2 000	0	0	0	45	-1 995.75	1.02	16.32	7.87	-43.32
Ghaghara	Bihar	23.15	3	1.9	22	6.22	1.734	2 000	0	0	0	45	-1 997	1.9	22	6.22	-43.266
Sone	Bihar	64.13	2	0.6	10.8	7.95	1.754	2 000	0	0	0	45	-1 998	0.6	10.8	7.95	-43.246
Hasdev	Chhattisgarh	13.11	11	5.3	66.45	4.2	0.95	2 000	0	0	0	45	-1 989	5.3	66.45	4.2	-44.05
Kharoon	Chhattisgarh	13.11	1	1.6	19.3	5.79	0.4	2 000	0	0	0	45	-1 999	1.6	19.3	5.79	-44.6
Mahanadi	Chattishgarh	20.97	8.3	3.2	14	4.59	0.82	2 000	0	0	0	45	-1 991.7	3.2	14	4.59	-44.18
Seonath	Chhattisgarh	13.11	1	1.8	27.6	5.85	0.495	2 000	0	0	0	45	-1 999	1.8	27.6	5.85	-44.505
Yamuna	Delhi	8.72	557	2.8	25.7	11	NA	2 000	0	0	0	45	-1 443	2.8	25.7	11	-45.0
Mandovi	Goa	36.28	4.8	2.2	5.5	4.66	0.14	2 000	0	0	0	45	-1 995.2	2.2	5.5	4.66	-44.86
Zuari	Goa	36.28	4.6	2.6	5.7	4.7	0.17	2 000	0	0	0	45	-1 995.4	2.6	5.7	4.7	-44.83
Damanganga	Gujarat	3.43	22	1.4	16.1	4	0.306	2 000	0	0	0	45	-1 978	1.4	16.1	4	-44.694
Khari	Gujarat	14.98	2 116	416	1 664	1.02	1.709	2 000	0	0	0	45	116	416	1664	1.02	-43.291
Mahi	Gujarat	1.29	152	1.9	13.9	7.6	0.06	2 000	0	0	0	45	-1 848	1.9	13.9	7.6	-44.94
Meshwa	Gujarat	13.34	37	2.2	18.1	11.4	0.516	2 000	0	0	0	45	-1 963	2.2	18.1	11.4	-44.484
Narmada	Gujarat	4.69	29	3	16	6.7	0.45	2 000	0	0	0	45	-1 971	3	16	6.7	-44.55
Sabarmati	Gujarat	1.72	173	41	108	11	0.53	2 000	0	0	0	45	-1 827	41	108	11	-44.47
Shedi	Gujarat	14.98	74	3	24.8	11.64	0.769	2 000	0	0	0	45	-1 926	3	24.8	11.64	-44.231
Tapi	Gujarat	4.29	33	3.3	22	8.5	0.24	2 000	0	0	0	45	-1 967	3.3	22	8.5	-44.76
Ghaggar	Haryana	23.43	292	9.6	31.3	4	0.4	2 000	0	0	0	45	-1 708	9.6	31.3	4	-44.6
Yamuna	Haryana	29.80	311	1.3	14.6	2.4	NA	2 000	0	0	0	45	-1 689	1.3	14.6	2.4	-45.0
Bean	Himachal Pradesh	25.60	15.1	0.47	4.2	3.4	0.44	2 000	0	0	0	45	-1 984.9	0.47	4.2	3.4	-44.56
Parvati	Himachal Pradesh	46.00	7	0.2	3	3.2	0.12	2 000	0	0	0	45	-1 993	0.2	3	3.2	-44.88
Ravi	Himachal Pradesh	10.09	15.5	0.4	6.4	3.95	0.2	2 000	0	0	0	45	-1 984.5	0.4	6.4	3.95	-44.8
Satluj	Himachal Pradesh	NA	27.6	1.4	5.83	3.51	0.119	2 000	0	0	0	45	-1 972.4	1.4	5.83	3.51	-44.881
Yamuna	Himachal Pradesh	2.73	NA	NA	NA	NA	NA	2 000	0	0	0	45	-2 000	0	0	0	-45.0
Subarnarekha	Jharkhand	4.64	150	2.9	6.3	8.5	NA	2 000	0	0	0	45	-1 850	2.9	6.3	8.5	-45.0

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River	State	Volume (km^3)	Acceptable water quality					Acceptable limit					Difference				
			Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)
Bhadra	Karnataka	13.11	29	4.3	38	6.7	0.26	2 000	0	0	0	45	-1 971	4.3	38	6.7	-44.74
Bhima	Karnataka	16.73	81	1.4	45	7.3	0.4	2 000	0	0	0	45	-1 919	1.4	45	7.3	-44.6
Cauvery	Karnataka	8.36	26	1	24.26	7.38	0.15	2 000	0	0	0	45	-1 974	1	24.26	7.38	-44.85
Ghat Prabha	Karnataka	9.46	30	1.65	49.4	7.3	0.3	2 000	0	0	0	45	-1 970	1.65	49.4	7.3	-44.7
Kabbani	Karnataka	8.16	25	1.1	27	6.8	NA	2 000	0	0	0	45	-1 975	1.1	27	6.8	-45.0
Krishna	Karnataka	15.52	46	1.2	42.3	7.3	0.16	2 000	0	0	0	45	-1 954	1.2	42.3	7.3	-44.84
Mal Prabha	Karnataka	12.57	44	1.4	52	7.3	0.47	2 000	0	0	0	45	-1 956	1.4	52	7.3	-44.53
Shimsha	Karnataka	16.73	37	7	31	7.38	0.158	2 000	0	0	0	45	-1 963	7	31	7.38	-44.842
Tungbhadra	Karnataka	3.85	41	1.3	23.6	7.3	0.29	2 000	0	0	0	45	-1 959	1.3	23.6	7.3	-44.71
Achenkoil	Kerala	4.31	5.5	0.5	7.5	7.21	0.38	2 000	0	0	0	45	-1 994.5	0.5	7.5	7.21	-44.62
Bhavani	Kerala	0	11	0.4	6.7	7.72	0.5	2 000	0	0	0	45	-1 989	0.4	6.7	7.72	-44.5
Chaliyar	Kerala	16.73	210	0.45	8	7.69	0.32	2 000	0	0	0	45	-1 790	0.45	8	7.69	-44.68
Kabbani	Kerala	8.57	6	0.4	4.7	7.0	NA	2 000	0	0	0	45	-1 994	0.4	4.7	7.0	-45.0
Manimala	Kerala	16.73	4.5	0.4	6.8	7.6	0.47	2 000	0	0	0	45	-1 995.5	0.4	6.8	7.6	-44.53
Pamba	Kerala	16.73	5.5	0.7	8.1	7.3	0.33	2 000	0	0	0	45	-1 994.5	0.7	8.1	7.3	-44.67
Periyar	Kerala	16.73	9.8	5.3	8.3	7.3	0.5	2 000	0	0	0	45	-1 990.2	5.3	8.3	7.3	-44.5
Betwa	Madhya Pradesh	13.57	NA	NA	NA	NA	NA	2 000	0	0	0	45	-2 000	0	0	0	-45.0
Chambal	Madhya Pradesh	9.56	172	8.5	60	6.01	0.73	2 000	0	0	0	45	-1 828	8.5	60	6.01	-44.27
Khan	Madhya Pradesh	NA	81	47.8	195.3	9.83	NA	2 000	0	0	0	45	-1 919	47.8	195.3	9.83	-45.0
Kshipra	Madhya Pradesh	34.5	77	6.8	62.8	9.875	NA	2 000	0	0	0	45	-1 923	6.8	62.8	9.875	-45.0
Mahi	Madhya Pradesh	0.89	NA	2.3	30.3	4.91	0.71	2 000	0	0	0	45	-2 000	2.3	30.3	4.91	-44.29
Mandakini	Madhya Pradesh	NA	321	2.8	41.3	4.46	0.23	2 000	0	0	0	45	-1 679	2.8	41.3	4.46	-44.77
Narmada	Madhya Pradesh	28.89	105	2.5	22	5.3	0.27	2 000	0	0	0	45	-1 895	2.5	22	5.3	-44.73
Sone	Madhya Pradesh	185.87	326	2.2	44	3.8	0.16	2 000	0	0	0	45	-1 674	2.2	44	3.8	-44.84
Tapi	Madhya Pradesh	5.11	227	2	24	5.18	0.5	2 000	0	0	0	45	-1 773	2	24	5.18	-44.5
Tons	Madhya Pradesh	26.85	337	2.6	32	4.22	0.19	2 000	0	0	0	45	-1 663	2.6	32	4.22	-44.81
Wainganga	Madhya Pradesh	26.4	17	5.2	38.5	5.4	0.05	2 000	0	0	0	45	-1 983	5.2	38.5	5.4	-44.95
Bhima	Maharashtra	30.55	33	5.2	24.85	4.2	0.57	2 000	0	0	0	45	-1 967	5.2	24.85	4.2	-44.43
Girna	Maharashtra	36.28	31	5.1	24.5	4.3	0.48	2 000	0	0	0	45	-1 969	5.1	24.5	4.3	-44.52
Godavari	Maharashtra	36.14	37.14	4.87	25.14	4.43	0.86	2 000	0	0	0	45	-1 962.86	4.87	25.14	4.43	-44.14
Krishna	Maharashtra	26.5	21	4.8	21.46	4.2	0.66	2 000	0	0	0	45	-1 979	4.8	21.46	4.2	-44.34
Nira	Maharashtra	36.28	41	4.9	56	4.4	0.57	2 000	0	0	0	45	-1 959	4.9	56	4.4	-44.43
Patalganga	Maharashtra	NA	21.5	4.75	26.1	4.3	0.34	2 000	0	0	0	45	-1 978.5	4.75	26.1	4.3	-44.66
Tapi	Maharashtra	5.11	37	5.3	26	4.2	0.6	2 000	0	0	0	45	-1 963	5.3	26	4.2	-44.4
Ulhas	Maharashtra	36.28	24	4.55	22.4	4.2	0.42	2 000	0	0	0	45	-1 976	4.55	22.4	4.2	-44.58
Wainganga	Maharashtra	15.37	18	6.8	24.7	NA	0.92	2 000	0	0	0	45	-1 982	6.8	24.7	0	-44.08
Wardha	Maharashtra	36.28	64	5.6	26	4.43	1.96	2 000	0	0	0	45	-1 936	5.6	26	4.43	-43.04
Imphal	Manipur	NA	31.5	2.2	4.6	5.92	0.12	2 000	0	0	0	45	-1 968.5	2.2	4.6	5.92	-44.88
Dhamsiri	Nagaland	0	NA	NA	NA	NA	NA	2 000	0	0	0	45	-2 000	0	0	0	-45.0

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Table 11 *Continued*

River	State	Volume (km^3)	Acceptable water quality: Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Acceptable limit: Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Difference: Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)
Baitami	Orissa	17.73	26.8	4.36	22.56	5.92	NA	2 000	0	0	0	45	-1 973.2	4.36	22.56	5.92	-45
Brahmani	Orissa	12.39	30.9	3.54	14.45	6.25	NA	2 000	0	0	0	45	-1 969.1	3.54	14.45	6.25	-45
I.B	Orissa	8.88	33	4.9	23.4	5.5	NA	2 000	0	0	0	45	-1 967	4.9	23.4	5.5	-45
Kuakhai	Orissa	NA	26	3.6	14.6	6.15	NA	2 000	0	0	0	45	-1 974	3.6	14.6	6.15	-45
Mahanadi	Orissa	29.02	27	4.1	19	5.8	NA	2 000	0	0	0	45	-1 973	4.1	19	5.8	-45
Nagavalli	Orissa	8.24	NA	NA	NA	NA	NA	2 000	0	0	0	45	-2 000	0	0	0	-45
Rushikulya	Orissa	13.11	77.5	17.8	75	3.24	NA	2 000	0	0	0	45	-1 922.5	17.8	75	3.24	-45
Subarnarekha	Orissa	1.07	NA	NA	NA	NA	NA	2 000	0	0	0	45	-2 000	0	0	0	-45
Bean	Punjab	20.94	1	7.4	16.7	4.5	1.52	2 000	0	0	0	45	-1 999	7.4	16.7	4.5	-43.48
Ghaggar	Punjab	14.66	1	20	39	4	NA	2 000	0	0	0	45	-1 999	20	39	4	-45
Ravi	Punjab	5.05	NA	0.8	1.9	3	0.665	2 000	0	0	0	45	-2 000	0.8	1.9	3	-44.335
Satluj	Punjab	NA	4.4	4.43	7.4	3.85	1.2	2 000	0	0	0	45	-1 995.6	4.43	7.4	3.85	-43.8
Chambal	Rajasthan	19.85	1	2.4	38	6.73	0.48	2 000	0	0	0	45	-1 999	2.4	38	6.73	-44.52
Mahi	Rajasthan	0.93	NA	2.4	39.4	7.22	0.359	2 000	0	0	0	45	-2 000	2.4	39.4	7.22	-44.641
Testa	Sikkim	24	NA	NA	NA	NA	NA	2 000	0	0	0	45	-2 000	0	0	0	-45
Bhavani	Tamil Nadu	16.73	33	15.27	43.5	11.1	0.5	2 000	0	0	0	45	-1 967	15.27	43.5	11.1	-44.5
Cauvery	Tamil Nadu	10.64	57	2.58	16.38	10.5	0.5	2 000	0	0	0	45	-1 943	2.58	16.38	10.5	-44.5
Tambiraparami	Tamil Nadu	16.73	NA	NA	NA	NA	NA	2 000	0	0	0	45	-2 000	0	0	0	-45
Betwa	Uttar Pradesh	20.93	39	2.2	17.7	12.26	0.54	2 000	0	0	0	45	-1 961	2.2	17.7	12.26	-44.46
Chambal	Uttar Pradesh	5.09	416	2.8	15.3	1	0.8	2 000	0	0	0	45	-1 584	2.8	15.3	1	-44.2
Ganga	Uttar Pradesh	149.01	12	2.61	15	8.92	0.4	2 000	0	0	0	45	-1 988	2.61	15	8.92	-44.6
Ghaghara	Uttar Pradesh	108.8	31	3.2	8.1	8.43	0.8	2 000	0	0	0	45	-1 969	3.2	8.1	8.43	-44.2
Gomti	Uttar Pradesh	250	54	5.03	19.76	9.52	0.42	2 000	0	0	0	45	-1 946	5.03	19.76	9.52	-44.58
Hindon	Uttar Pradesh	250	129	58	135	8.2	NA	2 000	0	0	0	45	-1 871	58	135	8.2	-45
Kalindi	Uttar Pradesh	NA	39	3.9	27.2	12.26	NA	2 000	0	0	0	45	-1 961	3.9	27.2	12.26	-45
Ramganga	Uttar Pradesh	151.33	46	3.9	25.7	9.53	NA	2 000	0	0	0	45	-1 954	3.9	25.7	9.53	-45
Rapti	Uttar Pradesh	250	32	3	7.3	NA	0.73	2 000	0	0	0	45	-1 968	3	7.3	0	-44.27
Rihand	Uttar Pradesh	93.75	NA	2.3	13	8.3	0.005	2 000	0	0	0	45	-2 000	2.3	13	8.3	-44.995
Sarju	Uttar Pradesh	195	NA	NA	NA	NA	NA	2 000	0	0	0	45	-2 000	0	0	0	-45
Yamuna	Uttar Pradesh	208.76	767	6.6	21.35	7.98	2.45	2 000	0	0	0	45	-1 233	6.6	21.35	7.98	-42.55
Baraker	West Bengal	250	159	4.8	23.3	NA	NA	2 000	0	0	0	45	-1 841	4.8	23.3	0	-45
Damodar	West Bengal	125.86	2025	2.42	35.6	11.39	0.01	2 000	0	0	0	45	25	2.42	35.6	11.39	-44.99
Ganga	West Bengal	51.49	538	1	16.75	11.2	0.22	2 000	0	0	0	45	-1 462	1	16.75	11.2	-44.78
Roopnarayam	West Bengal	250	1789	1.1	18.2	11.39	0.166	2 000	0	0	0	45	-211	1.1	18.2	11.39	-44.834

BOD – biochemical oxygen demand; COD – chemical oxygen demand; NA – not available; MPN – most probable number; NA – not available

Source Compiled by authors

Table 12

Deviation of actual quality (of water used for drinking purposes) from the acceptable limit in 2003

			Acceptable water quality					Acceptable limit					Difference				
River	State	Volume (km^3)	Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)
Godavari	Andhra Pradesh	40.16	275	5.2	5	3 198	NA	2 000	0	0	0	45	-1 725	5.2	5	3 198	-45
Krishna	Andhra Pradesh	15.98	2 864	1.96	31	9 617	NA	2 000	0	0	0	45	864	1.96	31	9 617	-45
Maner	Andhra Pradesh	6.81	436	2.45	10.5	149	NA	2 000	0	0	0	45	-1 564	2.45	10.5	149	-45
Manjeera	Andhra Pradesh	4.87	365	2.7	16	32 192	NA	2 000	0	0	0	45	-1 635	2.7	16	32 192	-45
Musi	Andhra Pradesh	5.54	1 488	11.65	94.2	892.5	3.7	2 000	0	0	0	45	-512	11.65	94.2	892.5	-41.3
Penner	Andhra Pradesh	6.16	774.5	2.75	15.5	781	0.935	2 000	0	0	0	45	-1 225.5	2.75	15.5	781	-44.065
Tungbhadra	Andhra Pradesh	9.26	630	2.15	13.4	NA	NA	2 000	0	0	0	45	-1 370	2.15	13.4	0	-45
Brahmaputra	Assam	18.29	222	1	13.08	571 565	NA	2 000	0	0	0	45	-1 778	1	13.08	571 565	-45
Dhansari	Assam	6.78	173	1.5	9.6	56 460	NA	2 000	0	0	0	45	-1 827	1.5	9.6	56 460	-45
Gandak	Bihar	119.05	384	1.2	19	1 138	NA	2 000	0	0	0	45	-1 616	1.2	19	1 138	-45
Ganga	Bihar	49.50	374	1.67	16.1	3 208	NA	2 000	0	0	0	45	-1626	1.67	16.1	3 208	-45
Ghaghara	Bihar	23.15	318	1.4	19.5	2 013	NA	2 000	0	0	0	45	-1 682	1.4	19.5	2 013	-45
Sone	Bihar	64.13	191	1.4	18.7	2 633	NA	2 000	0	0	0	45	-1 809	1.4	18.7	2 633	-45
Hasdev	Chhattisgarh	13.11	NA	2.1	26	290	2	2 000	0	0	0	45	-2 000	2.1	26	290	-43
Kharoon	Chhattisgarh	13.11	239	1.4	22.8	37	0.242	2 000	0	0	0	45	-1 761	1.4	22.8	37	-44.758
Mahanadi	Chhattisgarh	20.97	204	1.8	30.35	66.33	0.27	2 000	0	0	0	45	-1 796	1.8	30.35	66.33	-44.73
Seonath	Chhattisgarh	13.11	310	1.95	26.4	336	0.26	2 000	0	0	0	45	-1 690	1.95	26.4	336	-44.74
Yamuna	Delhi	8.72	653.5	17.8	58	85 796 668.5	NA	2 000	0	0	0	45	-1 346.5	17.8	58	85 796 669	-45
Mandovi	Goa	36.28	36 515	2.8	11	155	NA	2 000	0	0	0	45	34 515	2.8	11	155	-45
Zuari	Goa	36.28	24 318	2.3	11	163	NA	2 000	0	0	0	45	22 318	2.3	11	163	-45
Damanganga	Gujarat	3.43	5 755	2.85	42	60.17	10.5	2 000	0	0	0	45	3 755	2.85	42	60.17	-34.5
Khari	Gujarat	14.98	21 082	958.8	3 662.4	12 783 333	NA	2 000	0	0	0	45	19 082	958.8	3 662.4	12 783 333	-45
Mahi	Gujarat	1.29	281	1.14	13	45	NA	2 000	0	0	0	45	-1 719	1.14	13	45	-45
Meshwa	Gujarat	13.34	402	1.9	8	7 508	NA	2 000	0	0	0	45	-1 598	1.9	8	7508	-45
Narmada	Gujarat	4.69	268	1.2	16.75	68.75	NA	2 000	0	0	0	45	-1 732	1.2	16.75	68.75	-45
Sabarmati	Gujarat	1.72	1 208	40	277	375 003.33	NA	2 000	0	0	0	45	-792	40	277	375 003.3	-45
Shedi	Gujarat	14.98	1 241	20.6	101.3	79 395	NA	2 000	0	0	0	45	-759	20.6	101.3	79 395	-45
Tapi	Gujarat	4.29	337	1.93	3	574	0.3	2 000	0	0	0	45	-1 663	1.93	3	574	-44.7
Ghaggar	Haryana	23.43	844	9.3	78	NA	NA	2 000	0	0	0	45	-1 156	9.3	78	0	-45
Yamuna	Haryana	29.80	561.8	10.8	37.68	44 852 752.4	NA	2 000	0	0	0	45	-1 438.2	10.8	37.68	44 852 752	-45
Bean	Himachal Pradesh	25.60	209	1.36	3.7	935	NA	2 000	0	0	0	45	-1 791	1.36	3.7	935	-45
Parvati	Himachal Pradesh	46.00	189	0.7	8	592	NA	2 000	0	0	0	45	-1 811	0.7	8	592	-45
Ravi	Himachal Pradesh	10.09	192	0.75	2.5	40	NA	2 000	0	0	0	45	-1 808	0.75	2.5	40	-45
Satluj	Himachal Pradesh	NA	262	0.37	7.71	499	NA	2 000	0	0	0	45	-1 738	0.37	7.71	499	-45
Yamuna	Himachal Pradesh	2.73	1 045	3.4	42	137.5	NA	2 000	0	0	0	45	-955	3.4	42	137.5	-45
Subarnarekha	Jharkhand	4.64	209	1.87	31.75	1042	NA	2 000	0	0	0	45	-1 791	1.87	31.75	1042	-45

Continued

Table 12 *Continued*

River	State	Volume (km³)	Acceptable water quality: Conductivity (µ mhos/cm)	Acceptable water quality: BOD (mg/l)	Acceptable water quality: COD (mg/l)	Acceptable water quality: Total coliforms (MPN/100 ml)	Acceptable water quality: Nitrates (mg/l)	Acceptable limit: Conductivity (µ mhos/cm)	Acceptable limit: BOD (mg/l)	Acceptable limit: COD (mg/l)	Acceptable limit: Total coliforms (MPN/100 ml)	Acceptable limit: Nitrates (mg/l)	Difference: Conductivity (µ mhos/cm)	Difference: BOD (mg/l)	Difference: COD (mg/l)	Difference: Total coliforms (MPN/100 ml)	Difference: Nitrates (mg/l)
Bhadra	Karnataka	13.11	271	3.16	NA	1 552	0.19	2 000	0	0	0	45	-1 729	3.16	0	1 552	-44.81
Bhima	Karnataka	16.73	487	1.6	22.66	6 979	0.26	2 000	0	0	0	45	-1 513	1.6	22.66	6 979	-44.74
Cauvery	Karnataka	8.36	256	1.06	21.6	2 185	0.338	2 000	0	0	0	45	-1 744	1.06	21.6	2 185	-44.662
Ghat Prabha	Karnataka	9.46	525	1.75	71.7	1 019	NA	2 000	0	0	0	45	-1 475	1.75	71.7	1 019	-45
Kabbani	Karnataka	8.16	287	1.1	22	1 046	0.195	2 000	0	0	0	45	-1 713	1.1	22	1 046	-44.805
Krishna	Karnataka	15.52	317	1.65	22.8	2 967	0.21	2 000	0	0	0	45	-1 683	1.65	22.8	2 967	-44.79
Mal Prabha	Karnataka	12.57	447	1.46	27.16	1 406	NA	2 000	0	0	0	45	-1 553	1.46	27.16	1 406	-45
Shimsha	Karnataka	16.73	587	1.2	23	2 091	0.495	2 000	0	0	0	45	-1 413	1.2	23	2 091	-44.505
Tungbhadra	Karnataka	3.85	189	2.6	38	1 552	NA	2 000	0	0	0	45	-1 811	2.6	38	1 552	-45
Achenkoil	Kerala	4.31	66	1.9	25.6	5 550	0.35	2 000	0	0	0	45	-1 934	1.9	25.6	5 550	-44.65
Bhavani	Kerala	0	109	0.3	3.2	875	0.19	2 000	0	0	0	45	-1 891	0.3	3.2	875	-44.81
Chaliyar	Kerala	16.73	2 069	0.45	8.4	1 450	NA	2 000	0	0	0	45	69	0.45	8.4	1 450	-45
Kabbani	Kerala	8.57	81	0.6	3.2	825	0.15	2 000	0	0	0	45	-1 919	0.6	3.2	825	-44.85
Manimala	Kerala	16.73	58	0.7	14.4	3 062	0.348	2 000	0	0	0	45	-1 942	0.7	14.4	3 062	-44.652
Pamba	Kerala	16.73	1 117	1.1	20.8	14 866	0.93	2 000	0	0	0	45	-883	1.1	20.8	14 866	-44.07
Periyar	Kerala	16.73	334	1.4	6.4	390	0.02	2 000	0	0	0	45	-1 666	1.4	6.4	390	-44.98
Betwa	Madhya Pradesh	13.57	284	2.1	26	924	NA	2 000	0	0	0	45	-1 716	2.1	26	924	-45
Chambal	Madhya Pradesh	9.56	1 035	2.77	11.92	6 36 198	0.2	2 000	0	0	0	45	-965	2.77	11.92	636 198	-44.8
Khan	Madhya Pradesh	NA	1 546	30	NA	1 600	NA	2 000	0	0	0	45	-454	30	0	1 600	-45
Kshipra	Madhya Pradesh	34.5	820	4.9	20	NA	NA	2 000	0	0	0	45	-1 180	4.9	20	0	-45
Mahi	Madhya Pradesh	0.89	NA	NA	25	425	NA	2 000	0	0	0	45	-2 000	0	25	425	-45
Mandakini	Madhya Pradesh	NA	NA	6	NA	345	NA	2 000	0	0	0	45	-2 000	6	0	345	-45
Narmada	Madhya Pradesh	28.89	217	1.82	21.4	179	NA	2 000	0	0	0	45	-1 783	1.82	21.4	179	-45
Sone	Madhya Pradesh	185.87	191	1.6	18.7	666	NA	2 000	0	0	0	45	-1 809	1.6	18.7	666	-45
Tapi	Madhya Pradesh	5.11	132	1.26	17.33	126.66	NA	2 000	0	0	0	45	-1 868	1.26	17.33	126.66	-45
Tons	Madhya Pradesh	26.85	NA	5.95	NA	435.5	NA	2 000	0	0	0	45	-2 000	5.95	0	435.5	-45
Wainganga	Madhya Pradesh	26.4	353.5	2.25	20.5	292	NA	2 000	0	0	0	45	-1 646.5	2.25	20.5	292	-45
Bhima	Maharashtra	30.55	445	16.18	24	278	0.36	2 000	0	0	0	45	-1 555	16.18	24	278	-44.64
Girna	Maharashtra	36.28	295	6	5	254	NA	2 000	0	0	0	45	-1 705	6	5	254	-45
Godavari	Maharashtra	36.14	482	8.08	93	278	0.95	2 000	0	0	0	45	-1 518	8.08	93	278	-44.05
Krishna	Maharashtra	26.5	448	6.3	34	265	0.96	2 000	0	0	0	45	-1 552	6.3	34	265	-44.04
Nira	Maharashtra	36.28	398	6.5	NA	228	0.746	2 000	0	0	0	45	-1 602	6.5	0	228	-44.254
Patalganga	Maharashtra	NA	121	5.3	24	214	0.5	2 000	0	0	0	45	-1 879	5.3	24	214	-44.5
Tapi	Maharashtra	5.11	467	5.9	4.66	231	0.0655	2 000	0	0	0	45	-1 533	5.9	4.66	231	-44.9345
Ulhas	Maharashtra	36.28	128	5.7	32	218	0.47	2 000	0	0	0	45	-1 872	5.7	32	218	-44.53
Wainganga	Maharashtra	15.37	274	5.8	32	183	0.283	2 000	0	0	0	45	-1 726	5.8	32	183	-44.717
Wardha	Maharashtra	36.28	377	5.2	NA	173	0.95	2 000	0	0	0	45	-1 623	5.2	0	173	-44.05
Imphal	Manipur	NA	103	2.4	NA	60	NA	2 000	0	0	0	45	-1 897	2.4	0	60	-45
Dhamsiri	Nagaland	0	226	4.38	NA	NA	NA	2 000	0	0	0	45	-1 774	4.38	0	0	-45

Continued

River	State	Volume (km^3)	Acceptable water quality: Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Acceptable limit: Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Difference: Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)
Baitarni	Orissa	17.73	5642	1.66	NA	4 437	0.08	2 000	0	0	0	45	3 642	1.66	0	4 437	-44.92
Brahmani	Orissa	12.39	160	17	4.2	3 399	1.41	2 000	0	0	0	45	-1 840	17	4.2	3 399	-43.59
I.B	Orissa	8.88	147	1.55	NA	3 539	NA	2 000	0	0	0	45	-1 853	1.55	0	3 539	-45
Kuakhai	Orissa	NA	180	2.25	NA	4 779	NA	2 000	0	0	0	45	-1 820	2.25	0	4 779	-45
Mahanadi	Orissa	29.02	4585.5	1.86	24	5 706	NA	2 000	0	0	0	45	2 585.5	1.86	24	5 706	-45
Nagavalli	Orissa	8.24	431	2.25	NA	7 480	0.404	2 000	0	0	0	45	-1 569	2.25	0	7 480	-44.596
Rushikulya	Orissa	13.11	9206	1.8	NA	5 150	0.65	2 000	0	0	0	45	7 206	1.8	0	5 150	-44.35
Subarnarekha	Orissa	1.07	274	1.7	2330	NA	0.34	2 000	0	0	0	45	-1 726	1.7	2 330	0	-44.66
Bean	Punjab	20.94	277	2.06	6.22	783	NA	2 000	0	0	0	45	-1 723	2.06	6.22	783	-45
Ghaggar	Punjab	14.66	473	12	55	3 654	NA	2 000	0	0	0	45	-1 527	12	55	3 654	-45
Ravi	Punjab	5.05	493	12.8	25	2 944	NA	2 000	0	0	0	45	-1 507	12.8	25	2 944	-45
Satluj	Punjab	NA	387	4.52	12.58	5 076	NA	2 000	0	0	0	45	-1 613	4.52	12.58	5 076	-45
Chambal	Rajasthan	19.85	314.67	1.63	8.17	737	0.13	2 000	0	0	0	45	-1 685.33	1.63	8.17	737	-44.87
Mahi	Rajasthan	0.93	510	1.7	8.1	914	NA	2 000	0	0	0	45	-1 490	1.7	8.1	914	-45
Testa	Sikkim	24	278	8.55	NA	199	NA	2 000	0	0	0	45	-1 722	8.55	0	199	-45
Bhavani	Tamil Nadu	16.73	233	1.6	13.8	1 243	NA	2 000	0	0	0	45	-1 767	1.6	13.8	1 243	-45
Cauvery	Tamil Nadu	10.64	2823	2.13	53.3	1 083	NA	2 000	0	0	0	45	823	2.13	53.3	1 083	-45
Tambiraparami	Tamil Nadu	16.73	333	1.8	21.7	251	0.24	2 000	0	0	0	45	-1 667	1.8	21.7	251	-44.76
Betwa	Uttar Pradesh	20.93	284	2.1	27	1 100	NA	2 000	0	0	0	45	-1 716	2.1	27	1 100	-45
Chambal	Uttar Pradesh	5.09	548	2.2	11.9	2 542 583	NA	2 000	0	0	0	45	-1 452	2.2	11.9	2 542 583	-45
Ganga	Uttar Pradesh	149.01	257	2.91	17.05	21 330	0.846	2 000	0	0	0	45	-1 743	2.91	17.05	21 330	-44.154
Ghaghara	Uttar Pradesh	108.8	351	1.3	21.05	1 120	NA	2 000	0	0	0	45	-1 649	1.3	21.05	1 120	-45
Gomti	Uttar Pradesh	250	NA	2.5	15.5	18 798	1	2 000	0	0	0	45	-2 000	2.5	15.5	18 798	-44
Hindon	Uttar Pradesh	250	956	29.866	176	3 335 653.6	6.32	2 000	0	0	0	45	-1 044	29.866	176	3 335 654	-38.68
Kalindi	Uttar Pradesh	NA	703	34.92	219	163 305 562	17.66	2 000	0	0	0	45	-1 297	34.92	219	1.63	-27.34
Ramganga	Uttar Pradesh	151.33	446	4.7	NA	11 244	NA	2 000	0	0	0	45	-1 554	4.7	0	11 244	-45
Rapti	Uttar Pradesh	250	408	2.2	22.8	128	NA	2 000	0	0	0	45	-1 592	2.2	22.8	128	-45
Rihand	Uttar Pradesh	93.75	223.5	2	42	2 454	0.007	2 000	0	0	0	45	-1 776.5	2	42	2 454	-44.993
Sarju	Uttar Pradesh	195	331	3.3	16	6 975	NA	2 000	0	0	0	45	-1 669	3.3	16	6 975	-45
Yamuna	Uttar Pradesh	208.76	766	6.62	29.12	40 826 494	0.36	2 000	0	0	0	45	-1 234	6.62	29.12	40 826 494	-44.64
Baraker	West Bengal	250	NA	1.2	NA	70 000	NA	2 000	0	0	0	45	-2 000	1.2	0	70 000	-45
Damodar	West Bengal	125.86	891	1.83	16.4	252 179.6	0.138	2 000	0	0	0	45	-1 109	1.83	16.4	252 179.6	-44.862
Ganga	West Bengal	51.49	470	2.43	24.42	340 337	0.18	2 000	0	0	0	45	-1 530	2.43	24.42	340 337	-44.82
Roopnarayam	West Bengal	250	238	1.6	NA	2 383 335	NA	2 000	0	0	0	45	-1 762	1.6	0	2 383 335	-45

NA – not available; BOD – biochemical oxygen demand; COD – chemical oxygen demand; MPN – most probable number; NA – not available

Source Compiled by authors

Table 13

Deviation of actual quality (of water for irrigation use) from the acceptable limit in 1993

River	State	Volume (km³)	Acceptable water quality: Conductivity (µ mhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Acceptable limit: Conductivity (µ mhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Difference: Conductivity (µ mhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)
Godavari	Andhra Pradesh	40.16	9.5	2.27	9.1	NA	0.42	2 250	100	250	1 000	NA	-2 240.5	-97.73	-240.9	-1 000	NA
Krishna	Andhra Pradesh	15.98	346	1.85	9.1	7.3	0.5	2 250	100	250	1 000	NA	-1 904	-98.15	-240.9	-992.7	NA
Maner	Andhra Pradesh	6.81	323	1.8	6.7	NA	0.58	2 250	100	250	1 000	NA	-1 927	-98.2	-243.3	-1 000	NA
Manjeera	Andhra Pradesh	4.87	180	2.3	8.1	NA	0.927	2 250	100	250	1 000	NA	-2 070	-97.7	-241.9	-1 000	NA
Musi	Andhra Pradesh	5.54	775	7.8	27.6	NA	4.5	2 250	100	250	1 000	NA	-1 475	-92.2	-222.4	-1 000	NA
Penner	Andhra Pradesh	6.16	801	4.9	24	NA	1.3	2 250	100	250	1 000	NA	-1 449	-95.1	-226	-1 000	NA
Tungbhadra	Andhra Pradesh	9.26	595	2	7.1	NA	2.8	2 250	100	250	1 000	NA	-1 655	-98	-242.9	-1 000	NA
Brahmaputra	Assam	18.29	15	1	9.35	8.46	0.23	2 250	100	250	1 000	NA	-2 235	-99	-240.65	-991.54	NA
Dhansari	Assam	6.78	1.4	12.4	9.22	16	NA	2 250	100	250	1 000	NA	-2 248.6	-87.6	-240.78	-984	NA
Gandak	Bihar	119.05	3	1.3	19.6	8.33	1.81	2 250	100	250	1 000	NA	-2 247	-98.7	-230.4	-991.67	NA
Ganga	Bihar	49.50	4.25	1.02	16.32	7.87	1.68	2 250	100	250	1 000	NA	-2 245.75	-98.98	-233.68	-992.13	NA
Ghaghara	Bihar	23.15	3	1.9	22	6.22	1.734	2 250	100	250	1 000	NA	-2 247	-98.1	-228	-993.78	NA
Sone	Bihar	64.13	2	0.6	10.8	7.95	1.754	2 250	100	250	1 000	NA	-2 248	-99.4	-239.2	-992.05	NA
Hasdev	Chhattisgarh	13.11	11	5.3	66.45	4.2	0.95	2 250	100	250	1 000	NA	-2 239	-94.7	-183.55	-995.8	NA
Kharoon	Chhattisgarh	13.11	1	1.6	19.3	5.79	0.4	2 250	100	250	1 000	NA	-2 249	-98.4	-230.7	-994.21	NA
Mahanadi	Chhattisgarh	20.97	8.3	3.2	14	4.59	0.82	2 250	100	250	1 000	NA	-2 241.7	-96.8	-236	-995.41	NA
Seonath	Chhattisgarh	13.11	1	1.8	27.6	5.85	0.495	2 250	100	250	1 000	NA	-2 249	-98.2	-222.4	-994.15	NA
Yamuna	Delhi	8.72	557	2.8	25.7	11	NA	2 250	100	250	1 000	NA	-1 693	-97.2	-224.3	-989	NA
Mandovi	Goa	36.28	4.8	2.2	5.5	4.66	0.14	2 250	100	250	1 000	NA	-2 245.2	-97.8	-244.5	-995.34	NA
Zuari	Goa	36.28	4.6	2.6	5.7	4.7	0.17	2 250	100	250	1 000	NA	-2 245.4	-97.4	-244.3	-995.3	NA
Damanganga	Gujarat	3.43	22	1.4	16.1	4	0.306	2 250	100	250	1 000	NA	-2 228	-98.6	-233.9	-996	NA
Khari	Gujarat	14.98	2116	416	1 664	1.02	1.709	2 250	100	250	1 000	NA	-134	316	1 414	-998.98	NA
Mahi	Gujarat	1.29	152	1.9	13.9	7.6	0.06	2 250	100	250	1 000	NA	-2 098	-98.1	-236.1	-992.4	NA
Meshwa	Gujarat	13.34	37	2.2	18.1	11.4	0.516	2 250	100	250	1 000	NA	-2 213	-97.8	-231.9	-988.6	NA
Narmada	Gujarat	4.69	29	3	16	6.7	0.45	2 250	100	250	1 000	NA	-2 221	-97	-234	-993.3	NA
Sabarmati	Gujarat	1.72	173	41	108	11	0.53	2 250	100	250	1 000	NA	-2 077	-59	-142	-989	NA
Shedi	Gujarat	14.98	74	3	24.8	11.64	0.769	2 250	100	250	1 000	NA	-2 176	-97	-225.2	-988.36	NA
Tapi	Gujarat	4.29	33	3.3	22	8.5	0.24	2 250	100	250	1 000	NA	-2 217	-96.7	-228	-991.5	NA
Ghaggar	Haryana	23.43	292	9.6	31.3	4	0.4	2 250	100	250	1 000	NA	-1 958	-90.4	-218.7	-996	NA
Yamuna	Haryana	29.80	311	1.3	14.6	2.4	NA	2 250	100	250	1 000	NA	-1 939	-98.7	-235.4	-997.6	NA
Bean	Himachal Pradesh	25.60	15.1	0.47	4.2	3.4	0.44	2 250	100	250	1 000	NA	-2 234.9	-99.53	-245.8	-996.6	NA
Parvati	Himachal Pradesh	46.00	7	0.2	3	3.2	0.12	2 250	100	250	1 000	NA	-2 243	-99.8	-247	-996.8	NA
Ravi	Himachal Pradesh	10.09	15.5	0.4	6.4	3.95	0.2	2 250	100	250	1 000	NA	-2 234.5	-99.6	-243.6	-996.05	NA
Satluj	Himachal Pradesh	NA	27.6	1.4	5.83	3.51	0.119	2 250	100	250	1 000	NA	-2 222.4	-98.6	-244.17	-996.49	NA
Yamuna	Himachal Pradesh	2.73	NA	NA	NA	NA	NA	2 250	100	250	1 000	NA	-2 250	-100	-250	-1 000	NA
Subarnarekha	Jharkhand	4.64	150	2.9	6.3	8.5	NA	2 250	100	250	1 000	NA	-2 100	-97.1	-243.7	-991.5	NA

Continued

			Acceptable water quality					Acceptable limit					Difference				
River	State	Volume (km^3)	Conductivity (µ mhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Conductivity (µ mhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Conductivity (µ mhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)
Bhadra	Karnataka	13.11	29	4.3	38	6.7	0.26	2 250	100	250	1 000	NA	-2 221	-95.7	-212	-993.3	NA
Bhima	Karnataka	16.73	81	1.4	45	7.3	0.4	2 250	100	250	1 000	NA	-2 169	-98.6	-205	-992.7	NA
Cauvery	Karnataka	8.36	26	1	24.26	7.38	0.15	2 250	100	250	1 000	NA	-2 224	-99	-225.74	-992.62	NA
Ghat Prabha	Karnataka	9.46	30	1.65	49.4	7.3	0.3	2 250	100	250	1 000	NA	-2 220	-98.35	-200.6	-992.7	NA
Kabbani	Karnataka	8.16	25	1.1	27	6.8	NA	2 250	100	250	1 000	NA	-2 225	-98.9	-223	-993.2	NA
Krishna	Karnataka	15.52	46	1.2	42.3	7.3	0.16	2 250	100	250	1 000	NA	-2 204	-98.8	-207.7	-992.7	NA
Mal Prabha	Karnataka	12.57	44	1.4	52	7.3	0.47	2 250	100	250	1 000	NA	-2 206	-98.6	-198	-992.7	NA
Shimsha	Karnataka	16.73	37	7	31	7.38	0.158	2 250	100	250	1 000	NA	-2 213	-93	-219	-992.62	NA
Tungbhadra	Karnataka	3.85	41	1.3	23.6	7.3	0.29	2 250	100	250	1 000	NA	-2 209	-98.7	-226.4	-992.7	NA
Achenkoil	Kerala	4.31	5.5	0.5	7.5	7.21	0.38	2 250	100	250	1 000	NA	-2 244.5	-99.5	-242.5	-992.79	NA
Bhavani	Kerala	0.00	11	0.4	6.7	7.72	0.5	2 250	100	250	1 000	NA	-2 239	-99.6	-243.3	-992.28	NA
Chaliyar	Kerala	16.73	210	0.45	8	7.69	0.32	2 250	100	250	1 000	NA	-2 040	-99.55	-242	-992.31	NA
Kabbani	Kerala	8.57	6	0.4	4.7	7	NA	2 250	100	250	1 000	NA	-2 244	-99.6	-245.3	-993	NA
Manimala	Kerala	16.73	4.5	0.4	6.8	7.6	0.47	2 250	100	250	1 000	NA	-2 245.5	-99.6	-243.2	-992.4	NA
Pamba	Kerala	16.73	5.5	0.7	8.1	7.3	0.33	2 250	100	250	1 000	NA	-2 244.5	-99.3	-241.9	-992.7	NA
Periyar	Kerala	16.73	9.8	5.3	8.3	7.3	0.5	2 250	100	250	1 000	NA	-2 240.2	-94.7	-241.7	-992.7	NA
Betwa	Madhya Pradesh	13.57	NA	NA	NA	NA	NA	2 250	100	250	1 000	NA	-2 250	-100	-250	-1 000	NA
Chambal	Madhya Pradesh	9.56	172	8.5	60	6.01	0.73	2 250	100	250	1 000	NA	-2 078	-91.5	-190	-993.99	NA
Khan	Madhya Pradesh	NA	81	47.8	195.3	9.83	NA	2 250	100	250	1 000	NA	-2 169	-52.2	-54.7	-990.17	NA
Kshipra	Madhya Pradesh	34.50	77	6.8	62.8	9.875	NA	2 250	100	250	1 000	NA	-2 173	-93.2	-187.2	-990.125	NA
Mahi	Madhya Pradesh	0.89	NA	2.3	30.3	4.91	0.71	2 250	100	250	1 000	NA	-2 250	-97.7	-219.7	-995.09	NA
Mandakini	Madhya Pradesh	NA	321	2.8	41.3	4.46	0.23	2 250	100	250	1 000	NA	-1 929	-97.2	-208.7	-995.54	NA
Narmada	Madhya Pradesh	28.89	105	2.5	22	5.3	0.27	2 250	100	250	1 000	NA	-2 145	-97.5	-228	-994.7	NA
Sone	Madhya Pradesh	185.87	326	2.2	44	3.8	0.16	2 250	100	250	1 000	NA	-1 924	-97.8	-206	-996.2	NA
Tapi	Madhya Pradesh	5.11	227	2	24	5.18	0.5	2 250	100	250	1 000	NA	-2 023	-98	-226	-994.82	NA
Tons	Madhya Pradesh	26.85	337	2.6	32	4.22	0.19	2 250	100	250	1 000	NA	-1 913	-97.4	-218	-995.78	NA
Wainganga	Madhya Pradesh	26.40	17	5.2	38.5	5.4	0.05	2 250	100	250	1 000	NA	-2 233	-94.8	-211.5	-994.6	NA
Bhima	Maharashtra	30.55	33	5.2	24.85	4.2	0.57	2 250	100	250	1 000	NA	-2 217	-94.8	-225.15	-995.8	NA
Girna	Maharashtra	36.28	31	5.1	24.5	4.3	0.48	2 250	100	250	1 000	NA	-2 219	-94.9	-225.5	-995.7	NA
Godavari	Maharashtra	36.14	37.14	4.87	25.14	4.43	0.86	2 250	100	250	1 000	NA	-2 212.86	-95.13	-224.86	-995.57	NA
Krishna	Maharashtra	26.50	21	4.8	21.46	4.2	0.66	2 250	100	250	1 000	NA	-2 229	-95.2	-228.54	-995.8	NA
Nira	Maharashtra	36.28	41	4.9	56	4.4	0.57	2 250	100	250	1 000	NA	-2 209	-95.1	-194	-995.6	NA
Patalganga	Maharashtra	NA	21.5	4.75	26.1	4.3	0.34	2 250	100	250	1 000	NA	-2 228.5	-95.25	-223.9	-995.7	NA
Tapi	Maharashtra	5.11	37	5.3	26	4.2	0.6	2 250	100	250	1 000	NA	-2 213	-94.7	-224	-995.8	NA
Ulhas	Maharashtra	36.28	24	4.55	22.4	4.2	0.42	2 250	100	250	1 000	NA	-2 226	-95.45	-227.6	-995.8	NA
Wainganga	Maharashtra	15.37	18	6.8	24.7	NA	0.92	2 250	100	250	1 000	NA	-2 232	-93.2	-225.3	-1 000	NA
Wardha	Maharashtra	36.28	64	5.6	26	4.43	1.96	2 250	100	250	1 000	NA	-2 186	-94.4	-224	-995.57	NA
Imphal	Manipur	NA	31.5	2.2	4.6	5.92	0.12	2 250	100	250	1 000	NA	-2 218.5	-97.8	-245.4	-994.08	NA
Dhamsiri	Nagaland	0.00	NA	NA	NA	NA	NA	2 250	100	250	1 000	NA	-2 250	-100	-250	-1 000	NA
Baitarni	Orissa	17.73	26.8	4.36	22.56	5.92	NA	2 250	100	250	1 000	NA	-2 223.2	-95.64	-227.44	-994.08	NA

Continued

Table 13 *Continued*

River	State	Volume (km^3)	Acceptable water quality: Conductivity (µ mhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Acceptable limit: Conductivity (µ mhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Difference: Conductivity (µ mhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)
Brahmani	Orissa	12.39	30.9	3.54	14.45	6.25	NA	2 250	100	250	1 000	NA	-2 219.1	-96.46	-235.55	-993.75	NA
I.B	Orissa	8.88	33	4.9	23.4	5.5	NA	2 250	100	250	1 000	NA	-2 217	-95.1	-226.6	-994.5	NA
Kuakhai	Orissa	NA	26	3.6	14.6	6.15	NA	2 250	100	250	1 000	NA	-2 224	-96.4	-235.4	-993.85	NA
Mahanadi	Orissa	29.02	27	4.1	19	5.8	NA	2 250	100	250	1 000	NA	-2 223	-95.9	-231	-994.2	NA
Nagavalli	Orissa	8.24	NA	NA	NA	NA	NA	2 250	100	250	1 000	NA	-2 250	-100	-250	-1 000	NA
Rushikulya	Orissa	13.11	77.5	17.8	75	3.24	NA	2 250	100	250	1 000	NA	-2 172.5	-82.2	-175	-996.76	NA
Subarnarekha	Orissa	1.07	NA	NA	NA	NA	NA	2 250	100	250	1 000	NA	-2 250	-100	-250	-1 000	NA
Bean	Punjab	20.94	1	7.4	16.7	4.5	1.52	2 250	100	250	1 000	NA	-2 249	-92.6	-233.3	-995.5	NA
Ghaggar	Punjab	14.66	1.0	20.0	39.0	4.0	NA	2 250	100	250	1 000	NA	-2 249	-80	-211	-996	NA
Ravi	Punjab	5.05	NA	0.8	1.9	3	0.665	2 250	100	250	1 000	NA	-2 250	-99.2	-248.1	-997	NA
Satluj	Punjab	NA	4.4	4.43	7.4	3.85	1.2	2 250	100	250	1 000	NA	-2 245.6	-95.57	-242.6	-996.15	NA
Chambal	Rajasthan	19.85	1	2.4	38	6.73	0.48	2 250	100	250	1 000	NA	-2 249	-97.6	-212	-993.27	NA
Mahi	Rajasthan	0.93	NA	2.4	39.4	7.22	0.359	2 250	100	250	1 000	NA	-2 250	-97.6	-210.6	-992.78	NA
Testa	Sikkim	24.00	NA	NA	NA	NA	NA	2 250	100	250	1 000	NA	-2 250	-100	-250	-1 000	NA
Bhavani	Tamil Nadu	16.73	33	15.27	43.5	11.1	0.5	2 250	100	250	1 000	NA	-2 217	-84.73	-206.5	-988.9	NA
Cauvery	Tamil Nadu	10.64	57	2.58	16.38	10.5	0.5	2 250	100	250	1 000	NA	-2 193	-97.42	-233.62	-989.5	NA
Tambiraparami	Tamil Nadu	16.73	NA	NA	NA	NA	NA	2 250	100	250	1 000	NA	-2 250	-100	-250	-1 000	NA
Betwa	Uttar Pradesh	20.93	39	2.2	17.7	12.26	0.54	2 250	100	250	1 000	NA	-2 211	-97.8	-232.3	-987.74	NA
Chambal	Uttar Pradesh	5.09	416	2.8	15.3	1	0.8	2 250	100	250	1 000	NA	-1 834	-97.2	-234.7	-999	NA
Ganga	Uttar Pradesh	149.01	12	2.61	15	8.92	0.4	2 250	100	250	1 000	NA	-2 238	-97.39	-235	-991.08	NA
Ghaghara	Uttar Pradesh	108.80	31	3.2	8.1	8.43	0.8	2 250	100	250	1 000	NA	-2 219	-96.8	-241.9	-991.57	NA
Gomti	Uttar Pradesh	250.00	54	5.03	19.76	9.52	0.42	2 250	100	250	1 000	NA	-2 196	-94.97	-230.24	-990.48	NA
Hindon	Uttar Pradesh	250.00	129	58	135	8.2	NA	2 250	100	250	1 000	NA	-2 121	-42	-115	-991.8	NA
Kalindi	Uttar Pradesh	NA	39	3.9	27.2	12.26	NA	2 250	100	250	1 000	NA	-2 211	-96.1	-222.8	-987.74	NA
Ramganga	Uttar Pradesh	151.33	46	3.9	25.7	9.53	NA	2 250	100	250	1 000	NA	-2 204	-96.1	-224.3	-990.47	NA
Rapti	Uttar Pradesh	250.00	32	3	7.3	NA	0.73	2 250	100	250	1 000	NA	-2 218	-97	-242.7	-1 000	NA
Rihand	Uttar Pradesh	93.75	NA	2.3	13	8.3	0.005	2 250	100	250	1 000	NA	-2 250	-97.7	-237	-991.7	NA
Sarju	Uttar Pradesh	195.00	NA	NA	NA	NA	NA	2 250	100	250	1 000	NA	-2 250	-100	-250	-1 000	NA
Yamuna	Uttar Pradesh	208.76	767	6.6	21.35	7.98	2.45	2 250	100	250	1 000	NA	-1 483	-93.4	-228.65	-992.02	NA
Baraker	West Bengal	250.00	159	4.8	23.3	NA	NA	2 250	100	250	1 000	NA	-2 091	-95.2	-226.7	-1 000	NA
Damodar	West Bengal	125.86	2025	2.42	35.6	11.39	0.01	2 250	100	250	1 000	NA	-225	-97.58	-214.4	-988.61	NA
Ganga	West Bengal	51.49	538	1	16.75	11.2	0.22	2 250	100	250	1 000	NA	-1 712	-99	-233.25	-988.8	NA
Roopnarayam	West Bengal	250.00	1789	1.1	18.2	11.39	0.166	2 250	100	250	1 000	NA	-461	-98.9	-231.8	-988.61	NA

BOD – biochemical oxygen demand; COD – chemical oxygen demand; NA – not available; MPN – most probable number; NA – not available

Source Compiled by authors

Estimation of economic value of quality loss (cost of treatment)

Most of the studies accounting for freshwater resources take physical values of quantity and quality change. However, there are few cases wherein successful attempts have been made to capture the monetary value of the loss.

Methodology

Any value of water resources would entail identification of the eventual use of water for drinking, irrigation, industry, recreation, hydropower generation, and so on. Many of the uses of water do not impact upon the overall quantity of available water; examples include hydropower generation and recreation. However, they do have an impact on the quality of water. Ideally, biophysical data on various impacts of water are available in the scientific domain, but they are not amenable to economic valuation. The impact of water pollution on human health, ecosystem functioning, and biodiversity is known with great certainty but it is difficult to carry out its accounting and valuation as the relationships involved are non-linear and marked by the presence of thresholds and unimaginable synergy. They also change much more capriciously than the accounting entity.

In this monograph, the replacement cost method has been used. This method works on the assumption that society needs to incur resource (costs) to bring back the ecological attributes of the natural resources from the polluted state to the non-polluted state (acceptable level) prescribed by the CPCB. Here, the method also assumes that the social preference/willingness to spend the resource would be equal to individual's willingness to do so. The imputed degradation in the quality of water is sought to be reverted to the acceptable level. The treatment costs incurred in bringing the volume of polluted water back to the acceptable level for each state of India have been estimated at the unit rate derived from the representative sample plants in Noida and Ghaziabad.

Environmental costs resulting from economic activity, to which this principle cannot be applied, may be distinguished by costs caused and costs borne. Costs caused refer to the costs associated with the immediate effect of the economic activity on the environment at a specific place during a specific period. The costs borne refer to the costs associated with the direct and indirect effects of environmental degradation, regardless of the question of which economic activities have caused environmental degradation and when. Both the methods centre around health-related data, which is poorly maintained in India. Environmental costs can also be divided into input costs and actual costs, depending on whether costs are actually incurred (UNSD 1993). In this monograph, we have adopted the replacement cost approach where in the pollution caused during 1993–2003, over and above the accepted level of various pollutants, is supposed to be treated to bring it back to the original level of 1993. Needless to say, those standards would be different for different uses.

The volume of polluted water has been divided into three categories, drinking, irrigation, and industry, as each of them has different values of acceptable pollution limit. The usual national ratio of water going into irrigation, household, and industry is 8:1:1. So for each state, deviation from the acceptable limit and the corresponding water volume have been estimated. Subsequently, the volume of polluted water is supposed to be treated for each pollutant. But most of the technology comes in a package wherein all pollutants are treated simultaneously. The range in treatment technologies is also large. For the same treatment of BOD, COD, and other heavy metals, the costs of treatment vary between Rs 0.64 per cubic metre to Rs 1.98 per cubic metre. This figure has been derived from the average size of the treatment plants. It has been assumed that the cost of pollution is invariant with the intensity of pollutants and size of the treatment plant. This is on the basis of the information provided by the CPCB from their representative plants in Ghaziabad and Noida (Appendix 10). It is assumed that the polluted water for different purposes in different quantities is to be treated. The question is then what would be the cost of the treatment that an economy would need to incur. Tables 14 and 15 provide the necessary computation and figures.

Since the prevailing technologies give a range of values, both the ranges – higher and lower – have been obtained to arrive at the average figure of expenditure that would be needed to bring the polluted water back to the acceptable level.

To bring the water to the standards of drinking water, the calculation of costs was significant. For irrigation purpose, the treatment was either

Table 14

Cost of treatment of pollutants in surface water (by state)

State 1	*Total volume* (million m^3) 2	*Lower range treatment expenditure* (2*0.64) (Rs million) 3	*Upper range treatment expenditure* (2*1.99) (Rs million) 4	*Average treatment expenditure* (Rs million) 5
Andhra Pradesh	82 620	52 876.80	164 413.80	135 083.70
Assam	25 070	16 044.80	49 889.30	40 989.45
Bihar	255 830	163 731.20	509 101.70	418 282.05
Chhattisgarh	47 190	30 201.60	93 908.10	77 155.65
Delhi	8 720	5 580.80	17 352.80	14 257.20
Goa	72 560	46 438.40	144 394.40	118 635.60
Gujarat	53 140	34 009.60	105 748.60	86 883.90
Haryana	29 800	19 072.00	59 302.00	48 723.00
Himachal Pradesh	84 420	54 028.80	167 995.80	138 026.70
Jharkhand	4 640	2 969.60	9 233.60	7 586.40
Karnataka	104 490	66 873.60	207 935.10	170 841.15
Kerala	63 070	40 364.80	125 509.30	103 119.45
Madhya Pradesh	49 980	31 987.20	99 460.20	81 717.30
Maharashtra	222 510	142 406.40	442 794.90	363 803.85
Manipur	0	0.00	0.00	0.00
Nagaland	0	0.00	0.00	0.00
Orissa	90 440	57 881.60	179 975.60	147 869.40
Punjab	19 710	12 614.40	39 222.90	32 225.85
Rajasthan	0	0.00	0.00	0.00
Sikkim	24 000	15 360.00	47 760.00	39 240.00
Tamil Nadu	44 100	28 224.00	87 759.00	72 103.50
Uttar Pradesh	1 682 670	1 076 908.80	3 348 513.30	2 751 165.45
West Bengal	677 350	433 504.00	1 347 926.50	1 107 467.25
Total	2 428 120	1 553 996.80	4 831 958.80	3 969 976.20

Source Compiled by authors

Table 15

Cost of groundwater treatment

State 1	*Volume in study area* (million m^3) 2	*Lower range treatment expenditure* (2*0.64) (Rs million) 3	*Upper range treatment expenditure* (2*1.99) (Rs million) 4	*Average treatment expenditure* (Rs million) 5
Andhra Pradesh	20.97	13.4208	41.7303	34.28595
Assam	1 194.43	764.4352	2 376.9157	1 952.89305
Bihar	1 027	657.28	2 043.73	1 679.145
Delhi	162.7	104.128	323.773	266.0145
Himachal Pradesh	31.64	20.2496	62.9636	51.7314
Karnataka	3.52	2.2528	7.0048	5.7552
Kerala	38.01	NA	NA	NA
Maharashtra	2.46	1.5744	4.8954	4.0221
Madhya Pradesh	850.19	544.1216	1 691.8781	1 390.06065
Orissa	322.57	206.4448	641.9143	527.40195
Punjab	2.61	1.6704	5.1939	4.26735
Rajasthan	116.17	74.3488	231.1783	189.93795
Tamil Nadu	2 790.01	1 785.6064	5 552.1199	4 561.66635
Uttar Pradesh	1 494.68	956.5952	2 974.4132	2 443.8018
West Bengal	423.55	271.072	842.8645	692.50425

NA – not available

Source Compiled by authors

unavailable or not required at the national level. For industry uses, the data was not available. Therefore, while calculating the total cost of treatment, only water for drinking purposes is considered.

The costs of treating water for irrigation could not be estimated, as standards are not well defined. Some pollutants could prove beneficial to agriculture, such as N (nitrogen), P (phosphorus), and K (potassium), which act as fertilizer, and so on. Same is the case with water for industrial uses. Much depends upon the type of industry and the processes for which water is being used. Coolants of thermal power plant can use considerably polluted water without much of problem while the food–processing industry would require water that conforms to drinking water standards. The necessary information required to incorporate this into the present model was either unavailable or questionable. Hence, it was left unaccounted. This also suggests that the cost of water pollution estimated through the replacement cost approach is conservative at the most.

Appendix 10 provides the calculation of cost of damages with respect to quality of surface water and Appendix 11 shows the efficacy of the plants from where the cost data has been derived. The input and output quality shows that the plant is quite effective in treating the polluted water. In case of groundwater, there is only one data set and the deviation in pollution from the acceptable limit has been attributed to human activities (assumption). For surface water, the costs have been computed for the decline in quality for the period 1993–2003. By assuming a linear trend in the cost of treatment over the period 1993–2003, the average annual cost for surface water degradation has been computed in Table 16, and the cost of groundwater degradation is computed in Table 17.

Table 18 describes the lower and higher values of replacement costs of surface water and groundwater and Table 19 shows a summary of average

Table 16

Estimates of economic cost of treatment of degraded surface water

State	*Treatment expenditure for drinking purpose*			*Treatment expenditure for irrigation purpose*			*Treatment expenditure in industry*			*Total treatment expenditure*		
	Lower range (3*0.64) (Rs million)	*Upper range* (3*1.99) (Rs million)	*Average* (Rs million)	*Lower range* (3*0.64) (Rs million)	*Upper range* (3*1.99) (Rs million)	*Average* (Rs million)	*Lower range* (3*0.64) (Rs million)	*Upper range* (3*1.99) (Rs million)	*Average* (Rs million)	*Lower range* (3*0.64) (Rs million)	*Upper range* (3*1.99) (Rs million)	*Average* (Rs million)
1	2	3	4	5	6	7	8	9	10	11	12	13
Andhra Pradesh	52 876.80	164 413.80	135 083.70	NA	NA	NA	NA	NA	NA	52 876.80	164 413.80	135 083.70
Assam	16 044.80	49 889.30	40 989.45	NA	NA	NA	NA	NA	NA	16 044.80	49 889.30	40 989.45
Bihar	163 731.20	509 101.70	418 282.05	NA	NA	NA	NA	NA	NA	163 731.20	509 101.70	418 282.05
Chhattisgarh	30 201.60	93 908.10	77 155.65	NA	NA	NA	NA	NA	NA	30 201.60	93 908.10	77 155.65
Delhi	5 580.80	17 352.80	14 257.20	NA	NA	NA	NA	NA	NA	5 580.80	17 352.80	14 257.20
Goa	46 438.40	144 394.40	118 635.60	NA	NA	NA	NA	NA	NA	46 438.40	144 394.40	118 635.60
Gujarat	34 009.60	105 748.60	86 883.90	NA	NA	NA	NA	NA	NA	34 009.60	105 748.60	86 883.90
Haryana	19 072.00	59 302.00	48 723.00	NA	NA	NA	NA	NA	NA	19 072.00	59 302.00	48 723.00
Himachal Pradesh	54 028.80	167 995.80	138 026.70	NA	NA	NA	NA	NA	NA	54 028.80	167 995.80	138 026.70
Jharkhand	2 969.60	9 233.60	7 586.40	NA	NA	NA	NA	NA	NA	2 969.60	9 233.60	7 586.40
Karnataka	66 873.60	207 935.10	170 841.15	NA	NA	NA	NA	NA	NA	66 873.60	207 935.10	170 841.15
Kerala	40 364.80	125 509.30	103 119.45	NA	NA	NA	NA	NA	NA	40 364.80	125 509.30	103 119.45
Madhya Pradesh	31 987.20	99 460.20	81 717.30	NA	NA	NA	NA	NA	NA	31 987.20	99 460.20	81 717.30
Maharashtra	142 406.40	442 794.90	363 803.85	NA	NA	NA	NA	NA	NA	142 406.40	442 794.90	363 803.85
Manipur	0.00	0.00	0.00	NA	NA	NA	NA	NA	NA	0.00	0.00	0.00
Nagaland	0.00	0.00	0.00	NA	NA	NA	NA	NA	NA	0.00	0.00	0.00
Orissa	57 881.60	179 975.60	147 869.40	NA	NA	NA	NA	NA	NA	57 881.60	179 975.60	147 869.40
Punjab	12 614.40	39 222.90	32 225.85	NA	NA	NA	NA	NA	NA	12 614.40	39 222.90	32 225.85
Rajasthan	0.00	0.00	0.00	NA	NA	NA	NA	NA	NA	0.00	0.00	0.00
Sikkim	15 360.00	47 760.00	39 240.00	NA	NA	NA	NA	NA	NA	15 360.00	47 760.00	39 240.00
Tamil Nadu	28 224.00	87 759.00	72 103.50	NA	NA	NA	NA	NA	NA	28 224.00	87 759.00	72 103.50
Uttar Pradesh	1 076 908.80	3 348 513.30	2 751 165.45	NA	NA	NA	NA	NA	NA	1 076 908.80	3 348 513.30	2 751 165.45
West Bengal	433 504.00	1 347 926.50	1 107 467.25	NA	NA	NA	NA	NA	NA	433 504.00	1 347 926.50	1 107 467.25

NA – not available

Source Compiled by authors

Table 17

Groundwater degradation

State	*Treatment expenditure for drinking purpose*			*Treatment expenditure for irrigation purpose*			*Treatment expenditure in industry*			*Total treatment expenditure*		
	Lower range (*0.64) (Rs million)	*Upper range* (3*1.99) (Rs million)	*Average* (Rs million)	*Lower range* (*0.64) (Rs million)	*Upper range* (3*1.99) (Rs million)	*Average* (Rs million)	*Lower range* (*0.64) (Rs million)	*Upper range* (*1.99) (Rs million)	*Average* (Rs million)	*Lower range* (*0.64) (Rs million)	*Upper range* (3*1.99) (Rs million)	*Average* (Rs million)
Andhra Pradesh	13.42	41.73	34.29	NA	NA	NA	NA	NA	NA	13.42	41.73	34.29
Assam	764.44	2 376.92	1 952.89	NA	NA	NA	NA	NA	NA	764.44	2 376.92	1 952.89
Bihar	657.28	2 043.73	1 679.15	NA	NA	NA	NA	NA	NA	657.28	2 043.73	1 679.15
Delhi	104.13	323.77	266.01	NA	NA	NA	NA	NA	NA	104.13	323.77	266.01
Himachal Pradesh	20.25	62.96	51.73	NA	NA	NA	NA	NA	NA	20.25	62.96	51.73
Karnataka	2.25	7.00	5.76	NA	NA	NA	NA	NA	NA	2.25	7.00	5.76
Kerala	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Maharashtra	1.57	4.90	4.02	NA	NA	NA	NA	NA	NA	1.57	4.90	4.02
Madhya Pradesh	544.12	1 691.88	1 390.06	NA	NA	NA	NA	NA	NA	544.12	1 691.88	1 390.06
Orissa	206.44	641.91	527.40	NA	NA	NA	NA	NA	NA	206.44	641.91	527.40
Punjab	1.67	5.19	4.27	NA	NA	NA	NA	NA	NA	1.67	5.19	4.27
Rajasthan	74.35	231.18	189.94	NA	NA	NA	NA	NA	NA	74.35	231.18	189.94
Tamil Nadu	1 785.61	5 552.12	4 561.67	NA	NA	NA	NA	NA	NA	1 785.61	5 552.12	4 561.67
Uttar Pradesh	956.60	2 974.41	2443.80	NA	NA	NA	NA	NA	NA	956.60	2 974.41	2 443.80
West Bengal	271.07	842.86	692.50	NA	NA	NA	NA	NA	NA	271.07	842.86	692.50

NA – not available

Source Compiled by authors

Table 18

Estimates of economic cost of treatment of degraded fresh water in India during the period 1993–2003

State	*Treatment expenditure for surface water* Lower range (*0.64) (Rs million)	Upper range (3*1.99) (Rs million)	Average (Rs million)	*Treatment expenditure for groundwater* Lower range (*0.64) (Rs million)	Upper range (3*1.99) (Rs million)	Average (Rs million)	*Total treatment expenditure* Lower range (*0.64) (Rs million)	Upper range (*1.99) (Rs million)	Average (Rs million)
Andhra Pradesh	52 876.80	164 413.80	135 083.70	13.42	41.73	34.29	52 890.22	164 455.53	135 117.99
Assam	16 044.80	49 889.30	40 989.45	764.44	2 376.92	1 952.89	16 809.24	52 266.22	42 942.34
Bihar	163 731.20	509 101.70	418 282.05	657.28	2 043.73	1 679.15	164 388.48	511 145.43	419 961.20
Chhattisgarh	30 201.60	93 908.10	77 155.65	NA	NA	NA	30 201.60	93 908.10	77 155.65
Delhi	5 580.80	17 352.80	14 257.20	104.13	323.77	266.01	5 684.93	17 676.57	14 523.21
Goa	46 438.40	144 394.40	118 635.60	NA	NA	NA	46 438.40	144 394.40	118 635.60
Gujarat	34 009.60	105 748.60	86 883.90	NA	NA	NA	34 009.60	105 748.60	86 883.90
Haryana	19 072.00	59 302.00	48 723.00	NA	NA	NA	19 072.00	59 302.00	48 723.00
Himachal Pradesh	54 028.80	167 995.80	138 026.70	20.25	62.96	51.73	54 049.05	168 058.76	138 078.43
Jharkhand	2 969.60	9 233.60	7 586.40	NA	NA	NA	2 969.60	9 233.60	7 586.40
Karnataka	66 873.60	207 935.10	170 841.15	2.25	7.00	5.76	66 875.85	207 942.10	170 846.91
Kerala	40 364.80	125 509.30	103 119.45	NA	NA	NA	NA	NA	NA
Madhya Pradesh	31 987.20	99 460.20	81 717.30	544.12	1 691.88	1 390.06	32 531.32	101 152.08	83 107.36
Maharashtra	142 406.40	442 794.90	363 803.85	1.57	4.90	4.02	142 407.97	442 799.80	363 807.87
Manipur	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	0.00
Nagaland	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	0.00
Orissa	57 881.60	179 975.60	147 869.40	206.44	641.91	527.40	58 088.04	180 617.51	148 396.80
Punjab	12 614.40	39 222.90	32 225.85	1.67	5.19	4.27	12 616.07	39 228.09	32 230.12
Rajasthan	0.00	0.00	0.00	74.35	231.18	189.94	74.35	231.18	189.94
Sikkim	15 360.00	47 760.00	39 240.00	NA	NA	NA	15 360.00	47 760.00	39 240.00
Tamil Nadu	28 224.00	87 759.00	72 103.50	1 785.61	5 552.12	4 561.67	30 009.61	93 311.12	76 665.17
Uttar Pradesh	1 076 908.80	3 348 513.30	2 751 165.45	956.60	2 974.41	2 443.80	1 077 865.40	3 351 487.71	2 753 609.25
West Bengal	433 504.00	1 347 926.50	1 107 467.25	271.07	842.86	692.50	433 775.07	1 348 769.36	1 108 159.75

NA – not available

Source Compiled by authors

Table 19

Average annual loss due to degradation of fresh water

State	*Lower range treatment expenditure* (Rs million)	*Upper range treatment expenditure* (Rs million)	*Average expenditure* (Rs million)
Andhra Pradesh	5 289.02	16 445.55	13 511.80
Assam	1 680.92	5 226.62	4 294.23
Bihar	16 438.85	51 114.54	41 996.12
Chhattisgarh	3 020.16	9 390.81	7 715.57
Delhi	568.49	1 767.66	1 452.32
Goa	4 643.84	14 439.44	11 863.56
Gujarat	3 400.96	10 574.86	8 688.39
Haryana	1 907.20	5 930.20	4 872.30
Himachal Pradesh	5 404.90	16 805.88	13 807.84
Jharkhand	296.96	923.36	758.64
Karnataka	6 687.59	20 794.21	17 084.69
Kerala	NA	NA	NA
Madhya Pradesh	3 253.13	10 115.21	8 310.74
Maharashtra	14 240.80	44 279.98	36 380.79
Manipur	NA	NA	NA
Nagaland	NA	NA	NA
Orissa	5 808.80	18 061.75	14 839.68
Punjab	1 261.61	3 922.81	3 223.01
Rajasthan	7.43	23.12	18.99
Sikkim	1 536.00	4 776.00	3 924.00
Tamil Nadu	3 000.96	9 331.11	7 666.52
Uttar Pradesh	107 786.54	335 148.77	275 360.93
West Bengal	43 377.51	134 876.94	110 815.98

NA – not available

Source Compiled by authors

values. For Kerala, Manipur, and Nagaland, data on water pollution is not available. The figures in the table also suggest that for Andhra Pradesh, the annual damage to water resource (degradation and depletion) has been about Rs 13.5 billion during 1993–2003. The annual value of the damages done to the groundwater and surface water has been adjusted against the net state domestic product. This adjustment is over and above the conventional adjustment of depreciation in man-made capital. Table 20 provides the details.

It is clear from the table that for states like Bihar, Uttar Pradesh, Goa, West Bengal, Orissa, Maharashtra, Himachal Pradesh, and Karnataka, the adjusted state domestic products as a percentage of net state domestic product is below 98%. Examples include polluted states such as Uttar Pradesh (82.45%), Bihar (94.57%), and Orissa (96.17%). Coincidentally, these states are the poorest regions of the country. Going by the head count ratio of poverty, Bihar, Orissa, Uttar Pradesh, and West Bengal had the highest poverty during the period 1993–2003 (Dev and Ravi 2007). The high correlation between degradation of freshwater ecosystems and incidence of poverty is clear in this case. The water-deficient states like Haryana, Rajasthan, and Karnataka have less degradation of water where

Table 20

Adjustment in national accounts due to water pollution (in Rs million)

State 1	*GSDP (2002/03)* 2	*NSDP (2002/03)* 3	*Average depreciation in the stock of water* (Rs million) 4	*ESDP* (3-4) 5	*ESDP/NSDP* (5/3) 6	*Adjusted SDP as % of NSDP* (5/3*100) 7
Andhra Pradesh	1 607 684	1 439 754	13 511.8	1 426 242.2	0.99	99.06
Arunachal Pradesh	19 450.5	17 395.1	NA	NA	NA	NA
Assam	354 314.2	317 208	4 294.23	312 913.77	0.99	98.65
Bihar	897 150.2	787 033	42 754.76	744 278.24	0.95	94.57
Goa	77 711	67 356	11 863.56	55 492.44	0.82	82.39
Gujarat	1 382 850	1 144 047	8 688.39	1 135 358.61	0.99	99.24
Haryana	658 372	579 374	4 872.3	574 501.7	0.99	99.16
Himachal Pradesh	159 460	142 024	13 807.84	128 216.16	0.90	90.28
Jammu and Kashmir	147 495	128 052	NA	NA	NA	NA
Karnataka	1 139 292	1 004 063	17 084.69	986 978.31	0.98	98.30
Kerala	761 819	69 6021	NA	NA	NA	NA
Madhya Pradesh	1 132 756	974 607	16 026.31	958 580.69	0.98	98.36
Maharashtra	2 951 911	2 632 253	36 380.79	2 595 872.21	0.99	98.62
Manipur	35 312	32 047.8	NA	NA	NA	NA
Meghalaya	43 429	38 422.7	NA	NA	NA	NA
Mizoram	17 687.2	16 346.1	NA	NA	NA	NA
Nagaland	36 793.6	34 272	NA	NA	NA	NA
Orissa	446 844.5	387 373	14 839.68	372 533.32	0.96	96.17
Punjab	707 508.7	629 677.5	3 223.01	626 454.49	0.99	99.49
Rajasthan	873 717.5	768 878	18.99	768 859.01	1.00	100.00
Sikkim	11 527.3	10 386.5	3 924	6 462.5	0.62	62.22
Tamil Nadu	1 537 287	1 367 809	7 666.52	1 360 142.48	0.99	99.44
Tripura	60 616.9	56 603.4	NA	NA	NA	NA
Uttar Pradesh	1 796 015	1 568 625	275 360.93	1 293 264.07	0.82	82.45
West Bengal	1 671 371	1 537 807	110 815.98	1 426 991.02	0.93	92.79
UT (Union territories)	767 080	706 390	1 452.32[a]	704 937.68	1.00	99.79
Total	19 295 458	17 083 829	586 586.1	16 497 242.9	0.97	96.57

GSDP – gross state domestic product; NSDP – net state domestic product; ESDP – Environment Adjusted State Domestic Product; SDP – state domestic product; NA – not available

[a]The average value is available for Delhi only and not for other UTs, data for rest two UTs is not available.

Source Compiled by authors

the percentage is above 99%. Clearly, the poorest states are depleting their natural capital at an alarming rate and are not on a sustainable path

Conclusions

Accounting for fresh water is a vital step towards sustainability, particularly in India where about 70% of the geographical area is arid and semi-arid. Changes in the quantity and quality of surface water and groundwater functions affect ecosystem services and qualify to be treated in a manner analogous to man-made capital. The literature review presented in this monograph shows that various countries have succeeded in providing the accounts of water prescribed in the guidelines of the natural resource accounts of the United Nations.

In the present monograph, an attempt has been made to estimate the economic cost of deterioration in water quality, which has shown a steady decline over the period of study (1993–2003). Water has been divided into two categories, namely surface water and groundwater. While time-series data is available for surface water for the period 1993–2003, groundwater data is only available for the period 1994–95. Surface water quality is measured in terms of parameters such as BOD, COD, total coliforms, and conductivity, while for groundwater, the problem pertains to the presence of inorganic and organic compounds like arsenic, fluoride, and iron. Groundwater also has the additional problem of increased salinity. While surface water quality problems are mainly man made, the quality problems in groundwater can also be naturally occurring, and are aggravated by large-scale withdrawal of groundwater.

Our study has been divided informally into two parts: the first consists of an estimation of degradation of water quality from 1993–2003. The decline in the quality of both surface water and groundwater has been taken into consideration while assessing the total damage to the quality of water. For surface water, two types of deviations have been taken into consideration: one, change in water quality during the period 1993–2003, and second, deviations from standard (acceptable) limit. The total volume of water affected due to contamination has been estimated for both surface water and groundwater. For surface water, the total volume of all the affected rivers in each state has been added to get the total figure. For groundwater, the ratio of the affected area to the total state area has been approximated to get the final figure. Table 3 shows the extent of metal and inorganic minerals present in the groundwater in different states while Table 4 shows deviations from the acceptable limit. Tables 10–14 show deviations in the surface water over the period 1993–2003 along with the deviations from the acceptable limit.

The second part consists of monetizing the fall in water quality for both surface and underground supplies. The economic cost estimated is essentially a function of two variables, namely total volume of water quantity affected and amount of pollutant in that volume of water. For surface water, the cost of reverting water quality to the 1993 level and to the acceptable level has been estimated. For groundwater, the data shows that different states are inflicted with different types of pollutants. West Bengal faces arsenic problems, Gujarat and Tamil Nadu face serious problems of fluoride, and Madhya Pradesh is plagued with the problem of lead and manganese. BOD, COD, and total coliforms remain as generic problem in most of the states and have worsened during the period 1993–2003. Costs of both surface water and groundwater have been added to get the total economic cost or average depreciation in the stock of water.

The methodology used is the replacement cost approach and is very straightforward and logical in this case. The treatment cost has been projected for the volume of polluted water over and above the acceptable limit. The replacement cost has been obtained as the range due to variability in the abatement technology and associated costs. Thus, the annual damage in the water sector has been adjusted as is done in the case of depreciation of man-made capital.

Some of the key points that emerge from the results tabulated in Tables 19 and 20 are as follows.

- In states like Bihar, Orissa, Uttar Pradesh, and Sikkim, the incidence of pollution is quite high and, therefore, the stock of fresh water capital is depleted in these states.
- In industrialized states like Gujarat, Goa, and Tamil Nadu, the water availability may not be very high but these states face pollution at a larger scale. Groundwater pollution contributes significantly to the overall pollution and hence to the total cost of pollution abatement.
- Of the three major end-uses of water, namely industry, irrigation, and domestic supply for drinking, only the last use has been taken into account. Water is used in the ratio of 160:10:1 for these uses respectively. (In our study, we have only studied the cost of treatment for drinking water, as our data did not show that the water exceeded acceptable limits for industry and irrigation.) This monograph shows that the cost of treating only the water for drinking purposes is high. If the treatment of water for irrigation and industry was also required or if water quality continued to decline the result would be unsustainable. The cost of treatment would far exceed the state net GDP.
- The volume of groundwater to be treated has been taken as an approximation using the limited data available. Many of the problems in groundwater quality remain out of the purview of government data. If all the relevant data were made available, the situation would be shown to be more acute. Even though the CGWB (Central Ground Water Board) data maintains that volume of groundwater is constant, all studies regarding quality of groundwater show that water quality is changing. This is leading to problems of salinity and chemical seepage due to extensive use of water in the agriculture sector. Pure sources once contaminated are very difficult to recover as the treatment of groundwater at source is complex. If new groundwater blocks are added to the already long list of problem areas, then the cost of treatment would rise in a geometric fashion.
- Even without taking the above considerations into account, the depreciation of freshwater capital is equal to the net state domestic product of many states like Bihar, Uttar Pradesh, Goa, West Bengal, and so on. If the above considerations are also added up, then the depreciation of freshwater capital would be many times the state domestic product.

The accounting aptly conveys that the apparent growth in the domestic products of the states is thriving on the erosion of the natural capital base. The growth in the state GDP is clearly unsustainable and the accounting methodology and the concerned agencies must take note of this.

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Appendix 1

Details of contamination (by state) of groundwater in some areas of the districts due to various contaminants

State	*Salinity*	*Iron*	*Fluoride*	*Nitrate*	*Arsenic*	*Heavy metals*
Andhra Pradesh	East Godavari, West Godavari, Krishna, Guntur, Prakasam	–	Prakasam, Nellore, Anantapur, Nalgonda, Rangareddy, Adilabad	Vishakhapatnam, East Godavari, Krishna, Prakasam, Nellore, Chittoor, Anantapur, Cuddapah, Kurnool, Mehboobnagar, Rangareddy, Medak, Adilabad, Nalgonda, Khammam	–	Anantapur, Mehboob nagar, Prakasam, Visakhapatnam, Cuddapah, Nalgonda
Assam	–	Northern Bank of Brahmaputra	–	–	–	Digboi
Bihar	Begusarai	Champaran, Muzaffarpur, Gaya, Munger, Deoghar, Madhubani, Patna, Palamau, Nalanda, Nawada, Banka	Giridih, Jamui, Dhanbad	Palamau, Gaya, Patna, Nalanda, Nawada, Bhagalpur, Sahebgunj, Banka	–	Dhanbad, Muzaffarpur, Begusarai
Gujarat	Banaskantha, Junagarh, Bharauch, Surat, Mehsana, Ahmedabad, Surendranagar, Kheda, Jamnagar	–	Kachch, Surendranagar, Rajkot, Ahmedabad, Mehsana, Banaskantha, Sabarkantha.	–	–	–
Haryana	Sonepat, Rohtak, Hissar, Sirsa, Faridabad, Jind, Gurgaon, Bhiwani, Mahendragarh	–	Rohtak, Jind, Hissar, Bhiwani, Mahendragarh, Faridabad	Ambala, Sonepat, Jind, Gurgaon, Faridabad, Hissar, Sirsa, Karnal, Kurukshetra, Rohtak, Bhiwani, Mahendragarh	–	Faridabad
Himachal Pradesh	–	–	–	Kulu, Solan, Una	–	Purwanoo, Kalaamb
Karnataka	Bijapur, Belgaum, Raichur, Bellary, Dharwar	–	Tumkur, Kolar, Bangalore, Gulbarga, Bellary, Raichur	–	–	Bhadrawati

Continued

Appendix 1 *Continued*

State	*Salinity*	*Iron*	*Fluoride*	*Nitrate*	*Arsenic*	*Heavy metals*
Kerala	Ernakulam, Trichur, Alleppey	–	Palghat	–	–	–
Madhya Pradesh	Gwalior, Bhind, Morena, Jhabua, Khargaon, Dhar, Shivpuri, Shajapur, Guna, Mandsor, Ujjain	–	Bhind, Moerana, Guna, Jhabua, Chhindwara, Seoni, Mandla, Raipur, Vidisha	Sehore	–	Bastar, Korba, Ratlam, Nagda
Maharashtra	Amaravati, Akola	–	Bhandara, Chandrapur, Nanded, Aurangabad	Thane, Jalna, Beed, Nanded, Latur, Osmanabad, Solapur, Satara, Sangli, Kolhapur, Dhule, Jalgaon, Aurangabad, Ahmednagar, Pune, Buldana, Amravati, Akola, Nagpur, Wardha, Bhandara, Chandrapur, Gadchiroli	–	–
Orissa	Cuttack, Baleswar, Puri	Parts of Coastal Orissa	Bolangir	–	–	Angul, Talcher
Punjab	Bhatinda, Sangrur, Faridkot, Firozpur	–	Ludhiana, Faridkot, Bhatinda, Sangrur, Jalandhar, Amritsar	Patiala, Faridkot, Firozpur, Sangrur, Bhatinda	–	Ludhiana, Mandi, Gobindgarh
Rajasthan	Bharatpur, Jaipur, Nagaur, Jalore, Sirohi, Jodhpur	Bikaner, Alwar, Dungarpur	Barmer, Bikaner, Ganganagar, Jalore, Nagaur, Pali, Sirohi	Jaipur, Churu, Ganganagar, Bikaner, Jalore, Barmer, Bundi, Swai Madhopur	–	Pali, Udaipur, Khetri
Tamil Nadu	Karaikal, Pondicherry, Nagapattanam, Quide–Millet, Pudukottai, Ramananthapuram, North Arcot –Ambedkar, Dharampuri, Salem, Trichy, Coimbatore	–	Dharampuri, Salem, North Arcot–Ambedkar, Villipuram–Padayatchi, Muthuramalingam, Tiruchirapalli, Pudukottai	Coimbatore, Periyar, Salem	–	Manali, North Arcot

Continued

State	*Salinity*	*Iron*	*Fluoride*	*Nitrate*	*Arsenic*	*Heavy metals*
Tripura	–	Dharamnagar, Kauleshaher, Khowai, Ambasa, Amapur and Parts of Agartala Valley	–	–	–	–
Uttar Pradesh	Agra, Mathura, Mainpuri, Banmda.	–	Bulandshahar, Aligarh, Agra, Unnao, Rae–Bareli	Orai, Jhansi, Lalitpur, Faizabad, Sultanpur, Maharajganj, Gorakhapur, Deoria	–	Singrauli, Basti, Kanpur, Jaunpur, Allahabad, Saharanpur, Aligarh
West Bengal	–	Midnapore, Howrah, Hooghli, Bankura	Birbhum	Uttar Dinajpur, Malada, Birbhum, Nadia, Midnapur, Howrah, Murshidabad, Purulia	Malda, South–24 Paraganas, Nadia, Hoogly, Murshidabad, Bardhaman, Howrah	Durgapur, Howrah, Murshidabad, Nadia
National Capital Territory of Delhi	Najafgarh, Kanjhawala, and Mehrauli Blocks	–	–	City Shahdara and Mehrauli Blocks	–	Alipur, Kanjhawala, Najafgarh, Mehrauli City and Shahdara Blocks

Source CPCB (1995)

Appendix 2

Polluted stretches (by state) in rivers and lakes

State	*Number of water bodies*	*Number of rivers*	*Number of lakes/ tanks/drains, and so on*
Andhra Pradesh	8	3	5
Assam	2	2	
Delhi	1	1	
Jharkhand	1	1	
Gujarat	10	9	1
Haryana	3	2	1
Himachal Pradesh	2	1	1
Karnataka	6	4	2
Madhya Pradesh	5	4	1
Maharashtra	15	15	
Meghalaya	5	1	4
Orissa	5	5	
Punjab	3	3	
Rajasthan	3	3	
Tamil Nadu	7	7	
Sikkim	1	1	
Uttar Pradesh	8	8	
West Bengal	1	1	
Total	86	71	15

Source CPCB (1993, 1998)

Appendix 3

List of polluted river stretches

River	*Polluted stretch*	*Source/town*	*Critical parameters (in mg/l)*
Andhra Pradesh			
Godavari	Polavaram to D/S of Rajamundary	Rajamundary and Polavaram sewage	BOD: 6–12
Nagavalli	Nagavalli along Thotapalli Regulator	Industrial and domestic water from Rayagada	BOD: 6–10
Musi	D/S of Hyderabad sewage	Hyderabad–Securanderabad	BOD: 16–44
Lake	Kishtra Reddy Pet Tank, Medak	Medak sewage	BOD: 9–28
	Dharamsagar tank, Warangal	Warangal sewage	BOD: 7.5–9.4
	Hussain Sagar Lake	Hyderabad–Securandabad sewage	BOD: 8–19
	Sarronagar Lake	Ranga Reddy Hyderabad	BOD: 8.0–12.5
	Pulicate Lake, Nellore	Nellore sewage	BOD: 8–12.1
Assam			
Kalong	Elengabeel System	Nagaon sewage	BOD: 10–70
Bharalu	D/S Guwahati	Guwahati sewage	BOD: 38
Delhi			
Yamuna	Wazirabad to Okhla	Industrial and domestic waste from Delhi	BOD: 6–77
Jharkhand			
Subarnrekha	Ranchi to D/S of Jamshedpur	Industrial and domestic waste from Ranchi and Jamshedpur	BOD:
Gujarat			
Sabarmati	Ahmedabad to D/S of Vautha	Discharge from Meshwa and Ahemdabad	BOD: 56–504
	Kankoria Lake, Ahemdabad	Municipal and industrial waste from Ahemdabad	BOD: 6–29
Amlakhadi	Along Ankeshwar	Industrial and domestic waste from Ankeshwar	BOD: 138–920 Ammonia: 117.6–201.60

Continued

River	*Polluted stretch*	*Source/town*	*Critical parameters (in mg/l)*
Shedi	Along Kheda	Kheda sewage	BOD: 8–19
Damanganga	Vapi D/S to confluence with sea	Industrial and domestic waste from Vapi, Salvas, Daman and Kachigaon	BOD: 9–10
Ambika	Billimora D/S	Billimora sewage	BOD: 18
Bhadar	Jetpur to Ratia (Junagarh)	Jetpur and Dhoraji sewage	BOD: 33
Khari	Lali village, Ahemdabad		BOD: 92–675
Kolak	Vapi to Patalia.	Vapi Industrial township Phase-III, IV and Daman Industrial area	BOD: 11–35
Par	Vapi to Patalia	Atul township and industrial waste water, Pardi, and Umarkhadi waste water	BOD: 27
Haryana			
Ghaggar	Interstate border with Punjab to Ottu wier at Sirsa	Industrial and municipal waste from Sirsa	BOD: 8–50
Yamuna	Okhla to Kosi Kalan	Industrial and domestic waste from Faridabad and Palwal	BOD: 16
Drain No. 8	Sonepat to confluence with Yamuna	Industrial and domestic waste of Sonepat	BOD: 6–36
Himachal Pradesh			
Markanda	Kala Amb D/S to Haryana Border	Industrial and domestic waste from Kala Amb	BOD: 55 Colour: 1009 Hazen
Lake	Renuka Lake		BOD: 8
Karnataka			
Bhadra	Maleshwaram to D/S of Bhadravathi	Industrial and domestic waste from Bhadravathi	BOD: 7.2
Tunga	D/S of Shimoga	Shimoga sewage	BOD
Kali	Along Dandeli Town	West Coast Paper Mill waste	BOD
Tungabhadra	Harihar D/S to Hara eahalli Bridge.	Harihar sewage and Grasim waste	BOD: 6–8
Heballa Valley Lake	Mandya	Mandya sewage	BOD: 6–36
Ulsoor Lake		Bangalore sewage	BOD: 6–18
Madhya Pradesh			
Khan river	Indore city to confluence with Kshipra	Indore sewage	BOD: 65–120
Kshipra	Ujjain to confluence with Chambal	Ujjain sewage	BOD: 8–24
Chambal	D/S of Nagda	Industrial waste – Grasim and Nagda Sewage	BOD: 8–24
Tapi	D/S of Napanagar to Burhanpur city	Domestic and industrial waste water from Nepanagar and Burhanpur	BOD
Lower and Upper Lake, Bhopal		Bhopal sewage	BOD: 6–8
Maharashtra			
Godavari	Nasik to (Raher) Nanded	Sewage from Nasik, Chanderpur, Nanded, Raher	BOD: 6–66
Kalu	Atale village to Confluence with Ulhas		BOD: 6–10
Ulhas	Mohane to Baddapur	Industrial and domestic run-off Ulhasnagar	BOD: 6–8
Weinganga	D/S Ashti	Ashti town	BOD: 6–7
Panchganga	Along Ichalkaranji	Ichalkaranji	BOD: 7–25
Wardha	Along Rajura village	Paper mill waste	BOD: 6–8
Bhima	Pargaon to Confluence with river Daund	Pune Sewage Nira discharge	BOD: 6.5

Continued

Appendix 3 *Continued*

River	*Polluted stretch*	*Source/town*	*Critical parameters (in mg/l)*
Mula and Mutha	D/S Pune city	City sewage of Pune	BOD: 6.7
Bhatsa	D/S of shahpur Industrial township.	Industrial township, Shahpur	BOD
Patalganga	Khopoli to Esturaine region	Industrial and municipal sewage from khopoli, Rasayani, and Paundh	BOD: 6
Kundalika	Along Roha city	Roha city sewage	BOD: 6–6.5
Krishna	Dhomdam to Sangli	Sewage and industrial waste from Karnal and Sangli	BOD: 6–8
Tapi	Madhya Pradesh Border to Bhusaval	Bhusaval sewage	BOD: 6–9
Girna	Malegaon to confluence with Tapi	Malegaon sewage	BOD: 6–12
Nira	Along Pulgaon	Pulgaon Cotton Mill	BOD: 6–21
Meghalaya			
Kharkhala	Near Sutnga Khlieri, Jaintia Hills		BOD: 8–10
Umiam Lake, Barapani		Sewage from Shillong	BOD: 7–13
Wards Lake, Shillong			BOD: 9–12.2
Umtrew Lake, Byrnihat East			BOD: 7–9
Thadlaskein Lake Shillong		BOD: 7–9	
Orissa			
Brahmani	Panposh D/S to Dharamsala	Sewage and industrial waste from Panposh, Rourkela, Talcher, Dharamsala	BOD: 6–7
Ib	Sundargarh to confluence with Mahanadi	Sewage and industrial waste from Sundargarh, Jharsuguda, and Brajrajnagar	BOD: 6–9
Mahanadi	Cuttack D/S	Cuttack sewage	BOD: 6–8
Kuakhai	Along Bubhaneshwar	Bhubaneshwar sewage	BOD: 7
Kathjodi	Along Cuttack	Cuttack sewage	BOD: 6–12.3
Punjab			
Satluj	D/S of Ludhiana	Sewage from Ludhiana and Jalandar	BOD: 8–14.4
Beas	D/S of Mukorian	Industrial discharge from Goindwal and Mukarian	BOD: 8.4–20
Ghaggar	Mubarkpur to Sardulgarh	Municipal and industrial discharge from Patiala, Sukhna paper mills, and Derra Bassi	BOD: 6.4–50
Rajasthan			
Ghaggar	Ottu weir to Hanumangarh	Industrial and domestic waste from Haryana and Punjab	BOD
Chambal	D/S Kota city	Industrial and domestic waste from Kota	BOD: 6–6.4
Banas / Berach river	Udaipur to Chittorgarh	Municipal waste from Udaipur and Chittorgarh	BOD
Tamil Nadu			
Vaigai	Along Madurai	Madurai: industrial and domestic waste water	BOD: 7–9
Palar	Vaniyambadi	Vaniyambadi: industrial and municipal waste water	BOD
Adyar	Along Chennai	Chennai: industrial and municipal waste water	BOD
Coovum	Along Chennai	Chennai: industrial and municipal waste water	BOD
Tambiraparani	Papavinasam to Arunuganeri	Madura Coats industrial waste	BOD: 6–13

Continued

River	*Polluted stretch*	*Source/town*	*Critical parameters (in mg/l)*
Noyyal	Along coimbatoor, Tirupur, Palyanakotti	Industrial and domestic waste water from Coimbatore, Tirupur, and Palyanakotti	BOD
Cauvery	D/S of Mettur Dam to Erode city	Municipal sewage of Erode	BOD: 6.4–7
Sikkim			
Ranichu	Along Ranipur	Municipal waste water, Ranipur	BOD: 24
Uttar Pradesh			
Yamuna	Kosi Kalan to confluence with Chambal	Sewage from Agra, Vindravan, Mathura, and Etawah	BOD: 6–37
Hindon	Saharanpur to confluence with Yamuna	Sewage and industrial effluent from Saharanpur, Muzaffurnagar and Ghaziabad	BOD: 9–36
Western Kali	Muzaffar Nagar to confluence with Hindon	Sewage and industrial effluents from Muzaffarnagar and Mansoorpur	BOD: 21–44
Buri Yamuna	Pilkhani to Confluence with Yamauna	Industrial effluent of Pilkhani Distillary	BOD
Kali Nadi Eastern	Merrut to Kannauj	Industrial and municipal sewage from, Meerut, Modinagar, Bulandsahar, Hapur, Gulwati, and Kannauj	BOD: 43–135
Gomti	Lucknow to Confluence with Ganga	Sewage and industrial effluent from Lucknow, Sultanpur, and Jaunpur	BOD: 6–8.2 BOD: 6–7.6
Ganga	Kannauj to Kanpur D/S	Discharge through Kalinadi and Ramganga sewage and industrial effluent from Kannauaj and Kanpur	BOD: 6–10
	Varanasi D/S	Varanasi sewage and industrial effluent	BOD: 6.5–16.5
West Bengal			
Damodar	Durgapur to Haldia	Industrial waste and sewage from Durgapaur and Asansol	BOD: 6.4–32

BOD – biochemical oxygen demand
Source CPCB (1993, 1998)

Appendix 4

Polluted lakes/ tanks/drains

Name of tank/lake/drain/pond, and so on
Kishtra Reddy Pet Tank, Andhra Pradesh
Dharamsagar Tank, Andhra Pradesh
Hussain Sagar Lake, Andhra Pradesh
Sarronagar Lake, Andhra Pradesh
Pulicate Lake, Andhra Pradesh
Drain No. 8, Haryana
Renuka Lake, Himachal Pradesh
Heballa Valley Lake, Karnataka
Ulsoor Lake, Karnataka
Lower & Upper Lake, Madhya Pradesh
Umiam Lake, Meghalaya
Wards Lake, Meghalaya
Umtrew Lake, Meghalaya
Thadlaskein, Meghalaya
Kankoria Lake, Gujarat

Source CPCB (1993, 1998)

Appendix 5

Polluted stretches (by river)

River	*Number of polluted stretches*	River	*Number of polluted stretches*
Godavari	2	Mula and Mutha	1
Nagavalli	1	Bhatsa	1
Musi	1	Patalganga	1
Kalong	1	Kundalika	1
Bharalu	1	Krishna	1
Yamuna	3	Girna	1
Subranekha	1	Nira	1
Sabarmati	1	Kharkhala	1
Amlakhadi	1	Brahmani	1
Shedi	1	Ib	1
Damanganga	1	Mahanadi	1
Ambika	1	Kuakhai	1
Bhadar	1	Kathjodi	1
Khari	1	Satluj	1
Kolak	1	Beas	1
Par	1	Banas/Berach	1
Ghaggar	3	Vaigai	1
Markanda	1	Palar	1
Bhadra	1	Adyar	1
Tunga	1	Coovum	1
Kali	1	Tambiraparani	1
Tungabhadra	1	Noyyal	1
Khan	1	Cauvery	1
Kshipra	1	Ranichu	1
Chambal	2	Hindon	1
Tapi	2	Western Kali	1
Kalu	1	Buri Yamuna	1
Ulhas	1	Kali Nadi Eastern	1
Weinganga	1	Gomti	1
Panchganga	1	Ganga	2
Wardha	1	Damodar	1
Bhima	1	Total	71

Source CPCB (1993, 1998)

Appendix 6

Deviation of actual water quality from the acceptable limit for irrigation use in 2003

River	State	Volume (km^3)	Acceptable water quality: Conductivity (μ mhos/cm)	Acceptable water quality: BOD (mg/l)	Acceptable water quality: COD (mg/l)	Acceptable water quality: Total coliforms (MPN/100 ml)	Acceptable water quality: Nitrates (mg/l)	Acceptable limit: Conductivity (μ mhos/cm)	Acceptable limit: BOD (mg/l)	Acceptable limit: COD (mg/l)	Acceptable limit: Total coliforms (MPN/100 ml)	Acceptable limit: Nitrates (mg/l)	Difference: Conductivity (μ mhos/cm)	Difference: BOD (mg/l)	Difference: COD (mg/l)	Difference: Total coliforms (MPN/100 ml)	Difference: Nitrates (mg/l)
Godavari	Andhra Pradesh	40.16	275	5.2	5	3 198		2 250	100	250	1 000	NA	-1 975	-94.8	-245	2 198	NA
Krishna	Andhra Pradesh	15.98	2 864	1.96	31	9 617		2 250	100	250	1 000	NA	614	-98.04	-219	8 617	NA
Maner	Andhra Pradesh	6.81	436	2.45	10.5	149		2 250	100	250	1 000	NA	-1 814	-97.55	-239.5	-851	NA
Manjeera	Andhra Pradesh	4.87	365	2.7	16	32 192		2 250	100	250	1 000	NA	-1 885	-97.3	-234	31 192	NA
Musi	Andhra Pradesh	5.54	1 488	11.65	94.2	892.5	3.7	2 250	100	250	1 000	NA	-762	-88.35	-155.8	-107.5	NA
Penner	Andhra Pradesh	6.16	774.5	2.75	15.5	781	0.935	2 250	100	250	1 000	NA	-1 475.5	-97.25	-234.5	-219	NA
Tungbhadra	Andhra Pradesh	9.26	630	2.15	13.4			2 250	100	250	1 000	NA	-1 620	-97.85	-236.6	-1 000	NA
Brahmaputra	Assam	18.29	222	1	13.08	571 565		2 250	100	250	1 000	NA	-2 028	-99	-236.92	570 565	NA
Dhansari	Assam	6.78	173	1.5	9.6	56 460		2 250	100	250	1 000	NA	-2 077	-98.5	-240.4	55 460	NA
Gandak	Bihar	119.05	384	1.2	19	1 138		2 250	100	250	1 000	NA	-1 866	-98.8	-231	138	NA
Ganga	Bihar	49.50	374	1.67	16.1	3 208		2 250	100	250	1 000	NA	-1 876	-98.33	-233.9	2 208	NA
Ghaghara	Bihar	23.15	318	1.4	19.5	2 013		2 250	100	250	1 000	NA	-1 932	-98.6	-230.5	1 013	NA
Sone	Bihar	64.13	191	1.4	18.7	2 633		2 250	100	250	1 000	NA	-2 059	-98.6	-231.3	1 633	NA
Hasdev	Chhattisgarh	13.11		2.1	26	290	2	2 250	100	250	1 000	NA	-2 250	-97.9	-224	-710	NA
Kharoon	Chhattisgarh	13.11	239	1.4	22.8	37	0.242	2 250	100	250	1 000	NA	-2 011	-98.6	-227.2	-963	NA
Mahanadi	Chhattisgarh	20.97	204	1.8	30.35	66.33	0.27	2 250	100	250	1 000	NA	-2 046	-98.2	-219.65	-933.67	NA
Seonath	Chhattisgarh	13.11	310	1.95	26.4	336	0.26	2 250	100	250	1 000	NA	-1 940	-98.05	-223.6	-664	NA
Yamuna	Delhi	8.72	653.5	17.8	58	85 796 668.5		2 250	100	250	1 000	NA	-1 596.5	-82.2	-192	85 795 669	NA
Mandovi	Goa	36.28	36 515	2.8	11	155		2 250	100	250	1 000	NA	34 265	-97.2	-239	-845	NA
Zuari	Goa	36.28	24 318	2.3	11	163		2 250	100	250	1 000	NA	22 068	-97.7	-239	-837	NA
Damanganga	Gujarat	3.43	5 755	2.85	42	60.17	10.5	2 250	100	250	1 000	NA	3 505	-97.15	-208	-939.83	NA
Khari	Gujarat	14.98	21 082	958.8	3 662.4	12 783 333		2 250	100	250	1 000	NA	18 832	858.8	3412.4	12 782 333	NA
Mahi	Gujarat	1.29	281	1.14	13	45		2 250	100	250	1 000	NA	-1 969	-98.86	-237	-955	NA
Meshwa	Gujarat	13.34	402	1.9	8	7 508		2 250	100	250	1 000	NA	-1 848	-98.1	-242	6 508	NA
Narmada	Gujarat	4.69	268	1.2	16.75	68.75		2 250	100	250	1 000	NA	-1 982	-98.8	-233.25	-931.25	NA
Sabarmati	Gujarat	1.72	1 208	40	277	375 003.33		2 250	100	250	1 000	NA	-1 042	-60	27	374 003.3	NA
Shedi	Gujarat	14.98	1 241	20.6	101.3	79 395		2 250	100	250	1 000	NA	-1 009	-79.4	-148.7	78 395	NA
Tapi	Gujarat	4.29	337	1.93	3	574	0.3	2 250	100	250	1 000	NA	-1 913	-98.07	-247	-426	NA
Ghaggar	Haryana	23.43	844	9.3	78			2 250	100	250	1 000	NA	-1 406	-90.7	-172	-1 000	NA
Yamuna	Haryana	29.80	561.8	10.8	37.68	44 852 752.4		2 250	100	250	1 000	NA	-1 688.2	-89.2	-212.32	44 851 752	NA
Bean	Himachal Pradesh	25.60	209	1.36	3.7	935		2 250	100	250	1 000	NA	-2 041	-98.64	-246.3	-65	NA
Parvati	Himachal Pradesh	46.00	189	0.7	8	592		2 250	100	250	1 000	NA	-2 061	-99.3	-242	-408	NA
Ravi	Himachal Pradesh	10.09	192	0.75	2.5	40		2 250	100	250	1 000	NA	-2 058	-99.25	-247.5	-960	NA
Satluj	Himachal Pradesh	NA	262	0.37	7.71	499		2 250	100	250	1 000	NA	-1 988	-99.63	-242.29	-501	NA
Yamuna	Himachal Pradesh	2.73	1 045	3.4	42	137.5		2 250	100	250	1 000	NA	-1 205	-96.6	-208	-862.5	NA
Subarnarekha	Jharkhand	4.64	209	1.87	31.75	1 042		2 250	100	250	1 000	NA	-2 041	-98.13	-218.25	42	NA
Bhadra	Karnataka	13.11	271	3.16		1 552	0.19	2 250	100	250	1 000	NA	-1 979	-96.84	-250	552	NA

Continued

Appendix 6 *Continued*

River	State	Volume (km^3)	Acceptable water quality: Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Acceptable limit: Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)	Difference: Conductivity (µmhos/cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Nitrates (mg/l)
Bhima	Karnataka	16.73	487	1.6	22.66	6 979	0.26	2 250	100	250	1 000	NA	-1 763	-98.4	-227.34	5 979	NA
Cauvery	Karnataka	8.36	256	1.06	21.6	2 185	0.338	2 250	100	250	1 000	NA	-1 994	-98.94	-228.4	1 185	NA
Ghat Prabha	Karnataka	9.46	525	1.75	71.7	1 019		2 250	100	250	1 000	NA	-1 725	-98.25	-178.3	19	NA
Kabbani	Karnataka	8.16	287	1.1	22	1 046	0.195	2 250	100	250	1 000	NA	-1 963	-98.9	-228	46	NA
Krishna	Karnataka	15.52	317	1.65	22.8	2 967	0.21	2 250	100	250	1 000	NA	-1 933	-98.35	-227.2	1 967	NA
Mal Prabha	Karnataka	12.57	447	1.46	27.16	1 406		2 250	100	250	1 000	NA	-1 803	-98.54	-222.84	406	NA
Shimsha	Karnataka	16.73	587	1.2	23	2 091	0.495	2 250	100	250	1 000	NA	-1 663	-98.8	-227	1 091	NA
Tungbhadra	Karnataka	3.85	189	2.6	38	1 552		2 250	100	250	1 000	NA	-2 061	-97.4	-212	552	NA
Achenkoil	Kerala	4.31	66	1.9	25.6	5 550	0.35	2 250	100	250	1 000	NA	-2 184	-98.1	-224.4	4 550	NA
Bhavani	Kerala	0.00	109	0.3	3.2	875	0.19	2 250	100	250	1 000	NA	-2 141	-99.7	-246.8	-125	NA
Chaliyar	Kerala	16.73	2 069	0.45	8.4	1 450		2 250	100	250	1 000	NA	-181	-99.55	-241.6	450	NA
Kabbani	Kerala	8.57	81	0.6	3.2	825	0.15	2 250	100	250	1 000	NA	-2 169	-99.4	-246.8	-175	NA
Manimala	Kerala	16.73	58	0.7	14.4	3 062	0.348	2 250	100	250	1 000	NA	-2 192	-99.3	-235.6	2 062	NA
Pamba	Kerala	16.73	1 117	1.1	20.8	14 866	0.93	2 250	100	250	1 000	NA	-1 133	-98.9	-229.2	13 866	NA
Periyar	Kerala	16.73	334	1.4	6.4	390	0.02	2 250	100	250	1 000	NA	-1 916	-98.6	-243.6	-610	NA
Betwa	Madhya Pradesh	13.57	284	2.1	26	924		2 250	100	250	1 000	NA	-1 966	-97.9	-224	-76	NA
Chambal	Madhya Pradesh	9.56	1 035	2.77	11.92	636 198	0.2	2 250	100	250	1 000	NA	-1 215	-97.23	-238.08	635 198	NA
Khan	Madhya Pradesh	NA	1 546	30		1 600		2 250	100	250	1 000	NA	-704	-70	-250	600	NA
Kshipra	Madhya Pradesh	34.50	820	4.9	20			2 250	100	250	1 000	NA	-1 430	-95.1	-230	-1 000	NA
Mahi	Madhya Pradesh	0.89			25	425		2 250	100	250	1 000	NA	-2 250	-100	-225	-575	NA
Mandakini	Madhya Pradesh	NA		6		345		2 250	100	250	1 000	NA	-2 250	-94	-250	-655	NA
Narmada	Madhya Pradesh	28.89	217	1.82	21.4	179		2 250	100	250	1 000	NA	-2 033	-98.18	-228.6	-821	NA
Sone	Madhya Pradesh	185.87	191	1.6	18.7	666		2 250	100	250	1 000	NA	-2 059	-98.4	-231.3	-334	NA
Tapi	Madhya Pradesh	5.11	132	1.26	17.33	126.66		2 250	100	250	1 000	NA	-2 118	-98.74	-232.67	-873.34	NA
Tons	Madhya Pradesh	26.85		5.95		435.5		2 250	100	250	1 000	NA	-2 250	-94.05	-250	-564.5	NA
Wainganga	Madhya Pradesh	26.40	353.5	2.25	20.5	292		2 250	100	250	1 000	NA	-1 896.5	-97.75	-229.5	-708	NA
Bhima	Maharashtra	30.55	445	16.18	24	278	0.36	2 250	100	250	1 000	NA	-1 805	-83.82	-226	-722	NA
Girna	Maharashtra	36.28	295	6	5	254		2 250	100	250	1 000	NA	-1 955	-94	-245	-746	NA
Godavari	Maharashtra	36.14	482	8.08	93	278	0.95	2 250	100	250	1 000	NA	-1 768	-91.92	-157	-722	NA
Krishna	Maharashtra	26.50	448	6.3	34	265	0.96	2 250	100	250	1 000	NA	-1 802	-93.7	-216	-735	NA
Nira	Maharashtra	36.28	398	6.5		228	0.746	2 250	100	250	1 000	NA	-1 852	-93.5	-250	-772	NA
Patalganga	Maharashtra	NA	121	5.3	24	214	0.5	2 250	100	250	1 000	NA	-2 129	-94.7	-226	-786	NA
Tapi	Maharashtra	5.11	467	5.9	4.66	231	0.0655	2 250	100	250	1 000	NA	-1 783	-94.1	-245.34	-769	NA
Ulhas	Maharashtra	36.28	128	5.7	32	218	0.47	2 250	100	250	1 000	NA	-2 122	-94.3	-218	-782	NA
Wainganga	Maharashtra	15.37	274	5.8	32	183	0.283	2 250	100	250	1 000	NA	-1 976	-94.2	-218	-817	NA
Wardha	Maharashtra	36.28	377	5.2		173	0.95	2 250	100	250	1 000	NA	-1 873	-94.8	-250	-827	NA
Imphal	Manipur	NA	103	2.4		60		2 250	100	250	1 000	NA	-2 147	-97.6	-250	-940	NA
Dhamsiri	Nagaland	0.00	226	4.38				2 250	100	250	1 000	NA	-2 024	-95.62	-250	-1 000	NA
Baitarni	Orissa	17.73	5 642	1.66		4 437	0.08	2 250	100	250	1 000	NA	3 392	-98.34	-250	3 437	NA
Brahmani	Orissa	12.39	160	17	4.2	3 399	1.41	2 250	100	250	1 000	NA	-2 090	-83	-245.8	2 399	NA
IB	Orissa	8.88	147	1.55		3 539		2 250	100	250	1 000	NA	-2 103	-98.45	-250	2 539	NA
Kuakhai	Orissa	NA	180	2.25		4 779		2 250	100	250	1 000	NA	-2 070	-97.75	-250	3 779	NA

River	State	Volume (km³)	Acceptable water quality: Conductivity (µ mhos/ cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/ 100 ml)	Nitrates (mg/l)	Acceptable limit: Conductivity (µ mhos/ cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/ 100 ml)	Nitrates (mg/l)	Difference: Conductivity (µ mhos/ cm)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/ 100 ml)	Nitrates (mg/l)
Mahanadi	Orissa	29.02	4585.5	1.86	24	5 706		2 250	100	250	1 000	NA	2 335.5	-98.14	-226	4 706	NA
Nagavalli	Orissa	8.24	431	2.25		7 480	0.404	2 250	100	250	1 000	NA	-1 819	-97.75	-250	6 480	NA
Rushikulya	Orissa	13.11	9206	1.8		5 150	0.65	2 250	100	250	1 000	NA	6 956	-98.2	-250	4 150	NA
Subarnarekha	Orissa	1.07	274	1.7	2330		0.34	2 250	100	250	1 000	NA	-1 976	-98.3	2 080	-1 000	NA
Bean	Punjab	20.94	277	2.06	6.22	783		2 250	100	250	1 000	NA	-1 973	-97.94	-243.78	-217	NA
Ghaggar	Punjab	14.66	474.0	32.0	94.0	3 658.0		2 250	100	250	1 000	NA	-1 776	-68	-156	2 658	NA
Ravi	Punjab	5.05	493	12.8	25	2 944		2 250	100	250	1 000	NA	-1 757	-87.2	-225	1 944	NA
Satluj	Punjab	NA	387	4.52	12.58	5 076		2 250	100	250	1 000	NA	-1 863	-95.48	-237.42	4 076	NA
Chambal	Rajasthan	19.85	314.67	1.63	8.17	737	0.13	2 250	100	250	1 000	NA	-1 935.33	-98.37	-241.83	-263	NA
Mahi	Rajasthan	0.93	510	1.7	8.1	914		2 250	100	250	1 000	NA	-1 740	-98.3	-241.9	-86	NA
Testa	Sikkim	24.00	278	8.55		199		2 250	100	250	1 000	NA	-1 972	-91.45	-250	-801	NA
Bhavani	Tamil Nadu	16.73	233	1.6	13.8	1 243		2 250	100	250	1 000	NA	-2 017	-98.4	-236.2	243	NA
Cauvery	Tamil Nadu	10.64	2823	2.13	53.3	1 083		2 250	100	250	1 000	NA	573	-97.87	-196.7	83	NA
Tambiraparami	Tamil Nadu	16.73	333	1.8	21.7	251	0.24	2 250	100	250	1 000	NA	-1 917	-98.2	-228.3	-749	NA
Betwa	Uttar Pradesh	20.93	284	2.1	27	1 100		2 250	100	250	1 000	NA	-1 966	-97.9	-223	100	NA
Chambal	Uttar Pradesh	5.09	548	2.2	11.9	2 542 583		2 250	100	250	1 000	NA	-1 702	-97.8	-238.1	2 541 583	NA
Ganga	Uttar Pradesh	149.01	257	2.91	17.05	21 330	0.846	2 250	100	250	1 000	NA	-1 993	-97.09	-232.95	20 330	NA
Ghaghara	Uttar Pradesh	108.80	351	1.3	21.05	1 120		2 250	100	250	1 000	NA	-1 899	-98.7	-228.95	120	NA
Gomti	Uttar Pradesh	250.00		2.5	15.5	18 798	1	2 250	100	250	1 000	NA	-2 250	-97.5	-234.5	17 798	NA
Hindon	Uttar Pradesh	250.00	956	29.866	176	3 335 653.6	6.32	2 250	100	250	1 000	NA	-1 294	-70.134	-74	3 334 654	NA
Kalindi	Uttar Pradesh	NA	703	34.92	219	163 305 561.7	17.66	2 250	100	250	1 000	NA	-1 547	-65.08	-31	1.63E+08	NA
Ramganga	Uttar Pradesh	151.33	446	4.7		11 244		2 250	100	250	1 000	NA	-1 804	-95.3	-250	10 244	NA
Rapti	Uttar Pradesh	250.00	408	2.2	22.8	128		2 250	100	250	1 000	NA	-1 842	-97.8	-227.2	-872	NA
Rihand	Uttar Pradesh	93.75	223.5	2	42	2 454	0.007	2 250	100	250	1 000	NA	-2 026.5	-98	-208	1 454	NA
Sarju	Uttar Pradesh	195.00	331	3.3	16	6 975		2 250	100	250	1 000	NA	-1 919	-96.7	-234	5 975	NA
Yamuna	Uttar Pradesh	208.76	766	6.62	29.12	40 826 494	0.36	2 250	100	250	1 000	NA	-1 484	-93.38	-220.88	40 825 494	NA
Baraker	West Bengal	250.00		1.2		70 000		2 250	100	250	1 000	NA	-2 250	-98.8	-250	69 000	NA
Damodar	West Bengal	125.86	891	1.83	16.4	252 179.6	0.138	2 250	100	250	1 000	NA	-1 359	-98.17	-233.6	251 179.6	NA
Ganga	West Bengal	51.49	470	2.43	24.42	340 337	0.18	2 250	100	250	1 000	NA	-1 780	-97.57	-225.58	339 337	NA
Roopnarayam	West Bengal	250.00	238	1.6		2 383 335		2 250	100	250	1 000	NA	-2 012	-98.4	-250	2 382 335	NA

BOD – biochemical oxygen demand; COD – chemical oxygen demand; NA – not available; MPN – most probable number

Source Compiled by authors

Appendix 7

Acceptable limit difference of drinking water over the period 1993–2003

			2003			1993			2003 – 1993		
River	State	*Volume* (km^3)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100 ml)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100ml)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100ml)
Godavari	Andhra Pradesh	40.16	5.2	5	3 198	2.27	9.1	0	2.93	-4.1	3 198
Krishna	Andhra Pradesh	15.98	1.96	31	9 617	1.85	9.1	7.3	0.11	21.9	9 609.7
Maner	Andhra Pradesh	6.81	2.45	10.5	149	1.8	6.7	0	0.65	3.8	149
Manjeera	Andhra Pradesh	4.87	2.7	16	32 192	2.3	8.1	0	0.4	7.9	3 2192
Musi	Andhra Pradesh	5.54	11.65	94.2	892.5	7.8	27.6	0	3.85	66.6	892.5
Penner	Andhra Pradesh	6.16	2.75	15.5	781	4.9	24	0	-2.15	-8.5	781
Tungbhadra	Andhra Pradesh	9.26	2.15	13.4	0	2	7.1	0	0.15	6.3	0
Brahmaputra	Assam	18.29	1	13.08	571 565	1	9.35	8.46	0	3.73	571 556.5
Dhansari	Assam	6.78	1.5	9.6	56 460	12.4	9.22	16	-10.9	0.38	56 444
Gandak	Bihar	119.05	1.2	19	1 138	1.3	19.6	8.33	-0.1	-0.6	1 129.67
Ganga	Bihar	49.50	1.67	16.1	3 208	1.02	16.32	7.87	0.65	-0.22	3 200.13
Ghaghara	Bihar	23.15	1.4	19.5	2 013	1.9	22	6.22	-0.5	-2.5	2 006.78
Sone	Bihar	64.13	1.4	18.7	2 633	0.6	10.8	7.95	0.8	7.9	2 625.05
Hasdev	Chhattisgarh	13.11	2.1	26	290	5.3	66.45	4.2	-3.2	-40.45	285.8
Kharoon	Chhattisgarh	13.11	1.4	22.8	37	1.6	19.3	5.79	-0.2	3.5	31.21
Mahanadi	Chhattisgarh	20.97	1.8	30.35	66.33	3.2	14	4.59	-1.4	16.35	61.74
Seonath	Chhattisgarh	13.11	1.95	26.4	336	1.8	27.6	5.85	0.15	-1.2	330.15
Yamuna	Delhi	8.72	17.8	58	85 796 669	2.8	25.7	11	15	32.3	85 796 658
Mandovi	Goa	36.28	2.8	11	155	2.2	5.5	4.66	0.6	5.5	150.34
Zuari	Goa	36.28	2.3	11	163	2.6	5.7	4.7	-0.3	5.3	158.3
Damanganga	Gujarat	3.43	2.85	42	60.17	1.4	16.1	4	1.45	25.9	56.17
Khari	Gujarat	14.98	958.8	3 662.4	12 783 333	416	1664	1.02	542.8	1 998.4	12 783 332
Mahi	Gujarat	1.29	1.14	13	45	1.9	13.9	7.6	-0.76	-0.9	37.4
Meshwa	Gujarat	13.34	1.9	8	7 508	2.2	18.1	11.4	-0.3	-10.1	7 496.6
Narmada	Gujarat	4.69	1.2	16.75	68.75	3	16	6.7	-1.8	0.75	62.05
Sabarmati	Gujarat	1.72	40	277	375 003.3	41	108	11	-1	169	374 992.3
Shedi	Gujarat	14.98	20.6	101.3	79 395	3	24.8	11.64	17.6	76.5	79 383.36
Tapi	Gujarat	4.29	1.93	3	574	3.3	22	8.5	-1.37	-19	565.5
Ghaggar	Haryana	23.43	9.3	78	0	9.6	31.3	4	-0.3	46.7	-4
Yamuna	Haryana	29.80	10.8	37.68	44 852 752	1.3	14.6	2.4	9.5	23.08	44 852 750
Bean	Himachal Pradesh	25.60	1.36	3.7	935	0.47	4.2	3.4	0.89	-0.5	931.6
Parvati	Himachal Pradesh	46.00	0.7	8	592	0.2	3	3.2	0.5	5	588.8
Ravi	Himachal Pradesh	10.09	0.75	2.5	40	0.4	6.4	3.95	0.35	-3.9	36.05
Satluj	Himachal Pradesh	NA	0.37	7.71	499	1.4	5.83	3.51	-1.03	1.88	495.49

			2003			1993			2003 – 1993		
River	State	*Volume* (km^3)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100 ml)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100 ml)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100 ml)
Yamuna	Himachal Pradesh	2.73	3.4	42	137.5	0	0	0	3.4	42	137.5
Subarnarekha	Jharkhand	4.64	1.87	31.75	1 042	2.9	6.3	8.5	-1.03	25.45	1 033.5
Bhadra	Karnataka	13.11	3.16	0	1 552	4.3	38	6.7	-1.14	-38	1 545.3
Bhima	Karnataka	16.73	1.6	22.66	6 979	1.4	45	7.3	0.2	-22.34	6 971.7
Cauvery	Karnataka	8.36	1.06	21.6	2 185	1	24.26	7.38	0.06	-2.66	2 177.62
Ghat Prabha	Karnataka	9.46	1.75	71.7	1 019	1.65	49.4	7.3	0.1	22.3	1 011.7
Kabbani	Karnataka	8.16	1.1	22	1 046	1.1	27	6.8	0	-5	1 039.2
Krishna	Karnataka	15.52	1.65	22.8	2 967	1.2	42.3	7.3	0.45	-19.5	2 959.7
Mal Prabha	Karnataka	12.57	1.46	27.16	1 406	1.4	52	7.3	0.06	-24.84	1 398.7
Shimsha	Karnataka	16.73	1.2	23	2 091	7	31	7.38	-5.8	-8	2 083.62
Tungbhadra	Karnataka	3.85	2.6	38	1 552	1.3	23.6	7.3	1.3	14.4	1 544.7
Achenkoil	Kerala	4.31	1.9	25.6	5 550	0.5	7.5	7.21	1.4	18.1	5 542.79
Bhavani	Kerala	0.00	0.3	3.2	875	0.4	6.7	7.72	-0.1	-3.5	867.28
Chaliyar	Kerala	16.73	0.45	8.4	1 450	0.45	8	7.69	0	0.4	1 442.31
Kabbani	Kerala	8.57	0.6	3.2	825	0.4	4.7	7	0.2	-1.5	818
Manimala	Kerala	16.73	0.7	14.4	3 062	0.4	6.8	7.6	0.3	7.6	3 054.4
Pamba	Kerala	16.73	1.1	20.8	14 866	0.7	8.1	7.3	0.4	12.7	14 858.7
Periyar	Kerala	16.73	1.4	6.4	390	5.3	8.3	7.3	-3.9	-1.9	382.7
Betwa	Madhya Pradesh	13.57	2.1	26	924	0	0	0	2.1	26	924
Chambal	Madhya Pradesh	9.56	2.77	11.92	636 198	8.5	60	6.01	-5.73	-48.08	636 192
Khan	Madhya Pradesh	NA	30	0	1 600	47.8	195.3	9.83	-17.8	-195.3	1 590.17
Kshipra	Madhya Pradesh	34.50	4.9	20	0	6.8	62.8	9.875	-1.9	-42.8	-9.875
Mahi	Madhya Pradesh	0.89	0	25	425	2.3	30.3	4.91	-2.3	-5.3	420.09
Mandakini	Madhya Pradesh	NA	6	0	345	2.8	41.3	4.46	3.2	-41.3	340.54
Narmada	Madhya Pradesh	28.89	1.82	21.4	179	2.5	22	5.3	-0.68	-0.6	173.7
Sone	Madhya Pradesh	185.87	1.6	18.7	666	2.2	44	3.8	-0.6	-25.3	662.2
Tapi	Madhya Pradesh	5.11	1.26	17.33	126.66	2	24	5.18	-0.74	-6.67	121.48
Tons	Madhya Pradesh	26.85	5.95	0	435.5	2.6	32	4.22	3.35	-32	431.28
Wainganga	Madhya Pradesh	26.40	2.25	20.5	292	5.2	38.5	5.4	-2.95	-18	286.6
Bhima	Maharashtra	30.55	16.18	24	278	5.2	24.85	4.2	10.98	-0.85	273.8
Girna	Maharashtra	36.28	6	5	254	5.1	24.5	4.3	0.9	-19.5	249.7
Godavari	Maharashtra	36.14	8.08	93	278	4.87	25.14	4.43	3.21	67.86	273.57
Krishna	Maharashtra	26.50	6.3	34	265	4.8	21.46	4.2	1.5	12.54	260.8
Nira	Maharashtra	36.28	6.5	0	228	4.9	56	4.4	1.6	-56	223.6
Patalganga	Maharashtra	NA	5.3	24	214	4.75	26.1	4.3	0.55	-2.1	209.7
Tapi	Maharashtra	5.11	5.9	4.66	231	5.3	26	4.2	0.6	-21.34	226.8
Ulhas	Maharashtra	36.28	5.7	32	218	4.55	22.4	4.2	1.15	9.6	213.8
Wainganga	Maharashtra	15.37	5.8	32	183	6.8	24.7	0	-1	7.3	183
Wardha	Maharashtra	36.28	5.2	0	173	5.6	26	4.43	-0.4	-26	168.57

Continued

Appendix 7 *Continued*

River	State	Volume (km^3)	2003 BOD (mg/l)	2003 COD (mg/l)	2003 Total coliforms (MPN/100 ml)	1993 BOD (mg/l)	1993 COD (mg/l)	1993 Total coliforms (MPN/100 ml)	2003 – 1993 BOD (mg/l)	2003 – 1993 COD (mg/l)	2003 – 1993 Total coliforms (MPN/100 ml)
Imphal	Manipur	NA	2.4	0	60	2.2	4.6	5.92	0.2	-4.6	54.08
Dhamsiri	Nagaland	0.00	4.38	0	0	0	0	0	4.38	0	0
Baitarni	Orissa	17.73	1.66	0	4 437	4.36	22.56	5.92	-2.7	-22.56	4 431.08
Brahmani	Orissa	12.39	17	4.2	3 399	3.54	14.45	6.25	13.46	-10.25	3 392.75
I.B	Orissa	8.88	1.55	0	3 539	4.9	23.4	5.5	-3.35	-23.4	3 533.5
Kuakhai	Orissa	NA	2.25	0	4 779	3.6	14.6	6.15	-1.35	-14.6	4 772.85
Mahanadi	Orissa	29.02	1.86	24	5 706	4.1	19	5.8	-2.24	5	5 700.2
Nagavalli	Orissa	8.24	2.25	0	7 480	0	0	0	2.25	0	7480
Rushikulya	Orissa	13.11	1.8	0	5 150	17.8	75	3.24	-16	-75	5 146.76
Subarnarekha	Orissa	1.07	1.7	2 330	0	0	0	0	1.7	2330	0
Beas	Punjab	20.94	2.06	6.22	783	7.4	16.7	4.5	-5.34	-10.48	778.5
Ghaghar	Punjab	14.66	12	55	3 654	20	39	4	-8	16	3 650
Ravi	Punjab	5.05	12.8	25	2 944	0.8	1.9	3	12	23.1	2 941
Satluj	Punjab	NA	4.52	12.58	5 076	4.43	7.4	3.85	0.09	5.18	5 072.15
Chambal	Rajasthan	19.85	1.63	8.17	737	2.4	38	6.73	-0.77	-29.83	730.27
Mahi	Rajasthan	0.93	1.7	8.1	914	2.4	39.4	7.22	-0.7	-31.3	906.78
Testa	Sikkim	24.00	8.55	0	199	0	0	0	8.55	0	199
Bhavani	Tamil Nadu	16.73	1.6	13.8	1 243	15.27	43.5	11.1	-13.67	-29.7	1 231.9
Cauvery	Tamil Nadu	10.64	2.13	53.3	1 083	2.58	16.38	10.5	-0.45	36.92	1 072.5
Tambiraparami	Tamil Nadu	16.73	1.8	21.7	251	0	0	0	1.8	21.7	251
Betwa	Uttar Pradesh	20.93	2.1	27	1 100	2.2	17.7	12.26	-0.1	9.3	1 087.74
Chambal	Uttar Pradesh	5.09	2.2	11.9	2 542 583	2.8	15.3	1	-0.6	-3.4	2 542 582
Ganga	Uttar Pradesh	149.01	2.91	17.05	21 330	2.61	15	8.92	0.3	2.05	21 321.08
Ghaghara	Uttar Pradesh	108.80	1.3	21.05	1 120	3.2	8.1	8.43	-1.9	12.95	1 111.57
Gomti	Uttar Pradesh	250.00	2.5	15.5	18 798	5.03	19.76	9.52	-2.53	-4.26	18 788.48
Hindon	Uttar Pradesh	250.00	29.866	176	3 335 654	58	135	8.2	-28.134	41	3 335 645
Kalindi	Uttar Pradesh	NA	34.92	219	1.63E+08	3.9	27.2	12.26	31.02	191.8	1.63E+08
Ramganga	Uttar Pradesh	151.33	4.7	0	11 244	3.9	25.7	9.53	0.8	-25.7	11 234.47
Rapti	Uttar Pradesh	250.00	2.2	22.8	128	3	7.3	0	-0.8	15.5	128
Rihand	Uttar Pradesh	93.75	2	42	2 454	2.3	13	8.3	-0.3	29	2 445.7
Sarju	Uttar Pradesh	195.00	3.3	16	6 975	0	0	0	3.3	16	6 975
Yamuna	Uttar Pradesh	208.76	6.62	29.12	40 826 494	6.6	21.35	7.98	0.02	7.77	40 826 486
Baraker	West Bengal	250.00	1.2	0	70 000	4.8	23.3	0	-3.6	-23.3	70 000
Damodar	West Bengal	125.86	1.83	16.4	252 179.6	2.42	35.6	11.39	-0.59	-19.2	252 168.2
Ganga	West Bengal	51.49	2.43	24.42	340 337	1	16.75	11.2	1.43	7.67	340 325.8
Roopnarayam	West Bengal	250.00	1.6	0	2 383 335	1.1	18.2	11.39	0.5	-18.2	2 383 324

BOD – biochemical oxygen demand; COD – chemical oxygen demand; NA – not available; MPN – most probable number

Source Compiled by authors

Appendix 8

Acceptable limit difference of irrigation over the period 1993–2003

River	State	Volume (km^3)	2003 BOD (mg/l)	2003 COD (mg/l)	2003 Total coliforms (MPN/100 ml)	1993 BOD (mg/l)	1993 COD (mg/l)	1993 Total coliforms (MPN/100 ml)	2003 – 1993 BOD (mg/l)	2003 – 1993 COD (mg/l)	2003 – 1993 Total coliforms (MPN/100 ml)
Godavari	Andhra Pradesh	40.16	-94.8	-245	2 198	-97.73	-240.9	-1 000	2.93	-4.1	3 198
Krishna	Andhra Pradesh	15.98	-98.04	-219	8 617	-98.15	-240.9	-992.7	0.11	21.9	9 609.7
Maner	Andhra Pradesh	6.81	-97.55	-239.5	-851	-98.2	-243.3	-1 000	0.65	3.8	149
Manjeera	Andhra Pradesh	4.87	-97.3	-234	31 192	-97.7	-241.9	-1 000	0.4	7.9	32 192
Musi	Andhra Pradesh	5.54	-88.35	-155.8	-107.5	-92.2	-222.4	-1 000	3.85	66.6	892.5
Penner	Andhra Pradesh	6.16	-97.25	-234.5	-219	-95.1	-226	-1 000	-2.15	-8.5	781
Tungbhadra	Andhra Pradesh	9.26	-97.85	-236.6	-1 000	-98	-242.9	-1 000	0.15	6.3	0
Brahmaputra	Assam	18.29	-99	-236.92	570 565	-99	-240.65	-991.54	0	3.73	571 556.5
Dhansari	Assam	6.78	-98.5	-240.4	55 460	-87.6	-240.78	-984	-10.9	0.38	56 444
Gandak	Bihar	119.05	-98.8	-231	138	-98.7	-230.4	-991.67	-0.1	-0.6	1 129.67
Ganga	Bihar	49.50	-98.33	-233.9	2 208	-98.98	-233.68	-992.13	0.65	-0.22	3 200.13
Ghaghara	Bihar	23.15	-98.6	-230.5	1 013	-98.1	-228	-993.78	-0.5	-2.5	2 006.78
Sone	Bihar	64.13	-98.6	-231.3	1 633	-99.4	-239.2	-992.05	0.8	7.9	2 625.05
Hasdev	Chhattisgarh	13.11	-97.9	-224	-710	-94.7	-183.55	-995.8	-3.2	-40.45	285.8
Kharoon	Chhattisgarh	13.11	-98.6	-227.2	-963	-98.4	-230.7	-994.21	-0.2	3.5	31.21
Mahanadi	Chhattisgarh	20.97	-98.2	-219.65	-933.67	-96.8	-236	-995.41	-1.4	16.35	61.74
Seonath	Chhattisgarh	13.11	-98.05	-223.6	-664	-98.2	-222.4	-994.15	0.15	-1.2	330.15
Yamuna	Delhi	8.72	-82.2	-192	85 795 669	-97.2	-224.3	-989	15	32.3	85 796 658
Mandovi	Goa	36.28	-97.2	-239	-845	-97.8	-244.5	-995.34	0.6	5.5	150.34
Zuari	Goa	36.28	-97.7	-239	-837	-97.4	-244.3	-995.3	-0.3	5.3	158.3
Damanganga	Gujarat	3.43	-97.15	-208	-939.83	-98.6	-233.9	-996	1.45	25.9	56.17
Khari	Gujarat	14.98	858.8	3 412.4	12 782 333	316	1414	-998.98	542.8	1 998.4	12 783 332
Mahi	Gujarat	1.29	-98.86	-237	-955	-98.1	-236.1	-992.4	-0.76	-0.9	37.4
Meshwa	Gujarat	13.34	-98.1	-242	6 508	-97.8	-231.9	-988.6	-0.3	-10.1	7 496.6
Narmada	Gujarat	4.69	-98.8	-233.25	-931.25	-97	-234	-993.3	-1.8	0.75	62.05
Sabarmati	Gujarat	1.72	-60	27	374 003.3	-59	-142	-989	-1	169	374 992.3
Shedi	Gujarat	14.98	-79.4	-148.7	78 395	-97	-225.2	-988.36	17.6	76.5	79 383.36
Tapi	Gujarat	4.29	-98.07	-247	-426	-96.7	-228	-991.5	-1.37	-19	565.5
Ghaggar	Haryana	23.43	-90.7	-172	-1 000	-90.4	-218.7	-996	-0.3	46.7	-4
Yamuna	Haryana	29.80	-89.2	-212.32	44 851 752	-98.7	-235.4	-997.6	9.5	23.08	44 852 750
Bean	Himachal Pradesh	25.60	-98.64	-246.3	-65	-99.53	-245.8	-996.6	0.89	-0.5	931.6
Parvati	Himachal Pradesh	46.00	-99.3	-242	-408	-99.8	-247	-996.8	0.5	5	588.8
Ravi	Himachal Pradesh	10.09	-99.25	-247.5	-960	-99.6	-243.6	-996.05	0.35	-3.9	36.05
Satluj	Himachal Pradesh	NA	-99.63	-242.29	-501	-98.6	-244.17	-996.49	-1.03	1.88	495.49

Continued

Appendix 8 *Continued*

River	State	Volume (km^3)	2003 BOD (mg/l)	2003 COD (mg/l)	2003 Total coliforms (MPN/100 ml)	1993 BOD (mg/l)	1993 COD (mg/l)	1993 Total coliforms (MPN/100 ml)	2003 – 1993 BOD (mg/l)	2003 – 1993 COD (mg/l)	2003 – 1993 Total coliforms (MPN/100 ml)
Yamuna	Himachal Pradesh	2.73	-96.6	-208	-862.5	-100	-250	-1 000	3.4	42	137.5
Subarnarekha	Jharkhand	4.64	-98.13	-218.25	42	-97.1	-243.7	-991.5	-1.03	25.45	1 033.5
Bhadra	Karnataka	13.11	-96.84	-250	552	-95.7	-212	-993.3	-1.14	-38	1 545.3
Bhima	Karnataka	16.73	-98.4	-227.34	5 979	-98.6	-205	-992.7	0.2	-22.34	6 971.7
Cauvery	Karnataka	8.36	-98.94	-228.4	1 185	-99	-225.74	-992.62	0.06	-2.66	2 177.62
Ghat Prabha	Karnataka	9.46	-98.25	-178.3	19	-98.35	-200.6	-992.7	0.1	22.3	1 011.7
Kabbani	Karnataka	8.16	-98.9	-228	46	-98.9	-223	-993.2	0	-5	1 039.2
Krishna	Karnataka	15.52	-98.35	-227.2	1 967	-98.8	-207.7	-992.7	0.45	-19.5	2 959.7
Mal Prabha	Karnataka	12.57	-98.54	-222.84	406	-98.6	-198	-992.7	0.06	-24.84	1 398.7
Shimsha	Karnataka	16.73	-98.8	-227	1 091	-93	-219	-992.62	-5.8	-8	2 083.62
Tungbhadra	Karnataka	3.85	-97.4	-212	552	-98.7	-226.4	-992.7	1.3	14.4	1 544.7
Achenkoil	Kerala	4.31	-98.1	-224.4	4 550	-99.5	-242.5	-992.79	1.4	18.1	5 542.79
Bhavani	Kerala	0.00	-99.7	-246.8	-125	-996	-243.3	-992.28	-0.1	-3.5	867.28
Chaliyar	Kerala	16.73	-99.55	-241.6	450	-99.55	-242	-992.31	0	0.4	1 442.31
Kabbani	Kerala	8.57	-99.4	-246.8	-175	-99.6	-245.3	-993	0.2	-1.5	818
Manimala	Kerala	16.73	-99.3	-235.6	2 062	-99.6	-243.2	-992.4	0.3	7.6	3 054.4
Pamba	Kerala	16.73	-98.9	-229.2	13 866	-99.3	-241.9	-992.7	0.4	12.7	14 858.7
Periyar	Kerala	16.73	-98.6	-243.6	-610	-94.7	-241.7	-992.7	-3.9	-1.9	382.7
Betwa	Madhya Pradesh	13.57	-97.9	-224	-76	-100	-250	-1 000	2.1	26	924
Chambal	Madhya Pradesh	9.56	-97.23	-238.08	635 198	-91.5	-190	-993.99	-5.73	-48.08	636 192
Khan	Madhya Pradesh	NA	-70	-250	600	-52.2	-54.7	-990.17	-17.8	-195.3	1 590.17
Kshipra	Madhya Pradesh	34.50	-95.1	-230	-1 000	-93.2	-187.2	-990.125	-1.9	-42.8	-9.875
Mahi	Madhya Pradesh	0.89	-100	-225	-575	-97.7	-219.7	-995.09	-2.3	-5.3	420.09
Mandakini	Madhya Pradesh	NA	-94	-250	-655	-97.2	-208.7	-995.54	3.2	-41.3	340.54
Narmada	Madhya Pradesh	28.89	-98.18	-228.6	-821	-97.5	-228	-994.7	-0.68	-0.6	173.7
Sone	Madhya Pradesh	185.87	-98.4	-231.3	-334	-97.8	-206	-996.2	-0.6	-25.3	662.2
Tapi	Madhya Pradesh	5.11	-98.74	-232.67	-873.34	-98	-226	-994.82	-0.74	-6.67	121.48
Tons	Madhya Pradesh	26.85	-94.05	-250	-564.5	-97.4	-218	-995.78	3.35	-32	431.28
Wainganga	Madhya Pradesh	26.40	-97.75	-229.5	-708	-94.8	-211.5	-994.6	-2.95	-18	286.6
Bhima	Maharashtra	30.55	-83.82	-226	-722	-94.8	-225.15	-995.8	10.98	-0.85	273.8
Girna	Maharashtra	36.28	-94	-245	-746	-94.9	-225.5	-995.7	0.9	-19.5	249.7
Godavari	Maharashtra	36.14	-91.92	-157	-722	-95.13	-224.86	-995.57	3.21	67.86	273.57
Krishna	Maharashtra	26.50	-93.7	-216	-735	-95.2	-228.54	-995.8	1.5	12.54	260.8
Nira	Maharashtra	36.28	-93.5	-250	-772	-95.1	-194	-995.6	1.6	-56	223.6
Patalganga	Maharashtra	NA	-94.7	-226	-786	-95.25	-223.9	-995.7	0.55	-2.1	209.7
Tapi	Maharashtra	5.11	-94.1	-245.34	-769	-94.7	-224	-995.8	0.6	-21.34	226.8
Ulhas	Maharashtra	36.28	-94.3	-218	-782	-95.45	-227.6	-995.8	1.15	9.6	213.8
Wainganga	Maharashtra	15.37	-94.2	-218	-817	-93.2	-225.3	-1 000	-1	7.3	183
Wardha	Maharashtra	36.28	-94.8	-250	-827	-94.4	-224	-995.57	-0.4	-26	168.57

			2003			1993			2003 – 1993		
River	State	*Volume* (km^3)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100 ml)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100 ml)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100 ml)
Imphal	Manipur	NA	-97.6	-250	-940	-97.8	-245.4	-994.08	0.2	-4.6	54.08
Dhamsiri	Nagaland	0.00	-95.62	-250	-1 000	-100	-250	-1 000	4.38	0	0
Baitarni	Orissa	17.73	-98.34	-250	3 437	-95.64	-227.44	-994.08	-2.7	-22.56	4 431.08
Brahmani	Orissa	12.39	-83	-245.8	2 399	-96.46	-235.55	-993.75	13.46	-10.25	3 392.75
I.B	Orissa	8.88	-98.45	-250	2 539	-95.1	-226.6	-994.5	-3.35	-23.4	3 533.5
Kuakhai	Orissa	NA	-97.75	-250	3 779	-96.4	-235.4	-993.85	-1.35	-14.6	4 772.85
Mahanadi	Orissa	29.02	-98.14	-226	4 706	-95.9	-231	-994.2	-2.24	5	5 700.2
Nagavalli	Orissa	8.24	-97.75	-250	6 480	-100	-250	-1 000	2.25	0	7 480
Rushikulya	Orissa	13.11	-98.2	-250	4 150	-82.2	-175	-996.76	-16	-75	5 146.76
Subarnarekha	Orissa	1.07	-98.3	2080	-1 000	-100	-250	-1 000	1.7	2330	0
Bean	Punjab	20.94	-97.94	-243.78	-217	-92.6	-233.3	-995.5	-5.34	-10.48	778.5
Ghaggar	Punjab	14.66	-68	-156	2 658	-80	-211	-996	12	55	3 654
Ravi	Punjab	5.05	-87.2	-225	1 944	-99.2	-248.1	-997	12	23.1	2 941
Satluj	Punjab	NA	-95.48	-237.42	4 076	-95.57	-242.6	-996.15	0.09	5.18	5 072.15
Chambal	Rajasthan	19.85	-98.37	-241.83	-263	-97.6	-212	-993.27	-0.77	-29.83	730.27
Mahi	Rajasthan	0.93	-98.3	-241.9	-86	-97.6	-210.6	-992.78	-0.7	-31.3	906.78
Testa	Sikkim	24.00	-91.45	-250	-801	-100	-250	-1 000	8.55	0	199
Bhavani	Tamil Nadu	16.73	-98.4	-236.2	243	-84.73	-206.5	-988.9	-13.67	-29.7	1 231.9
Cauvery	Tamil Nadu	10.64	-97.87	-196.7	83	-97.42	-233.62	-989.5	-0.45	36.92	1 072.5
Tambiraparami	Tamil Nadu	16.73	-98.2	-228.3	-749	-100	-250	-1 000	1.8	21.7	251
Betwa	Uttar Pradesh	20.93	-97.9	-223	100	-97.8	-232.3	-987.74	-0.1	9.3	1 087.74
Chambal	Uttar Pradesh	5.09	-97.8	-238.1	2 541 583	-97.2	-234.7	-999	-0.6	-3.4	2 542 582
Ganga	Uttar Pradesh	149.01	-97.09	-232.95	20 330	-97.39	-235	-991.08	0.3	2.05	21 321.08
Ghaghara	Uttar Pradesh	108.80	-98.7	-228.95	120	-96.8	-241.9	-991.57	-1.9	12.95	1 111.57
Gomti	Uttar Pradesh	250.00	-97.5	-234.5	17 798	-94.97	-230.24	-990.48	-2.53	-4.26	18 788.48
Hindon	Uttar Pradesh	250.00	-70.134	-74	3 334 654	-42	-115	-991.8	-28.134	41	3 335 645
Kalindi	Uttar Pradesh	NA	-65.08	-31	1.63E+08	-96.1	-222.8	-987.74	31.02	191.8	1.63E+08
Ramganga	Uttar Pradesh	151.33	-95.3	-250	10 244	-96.1	-224.3	-990.47	0.8	-25.7	11 234.47
Rapti	Uttar Pradesh	250.00	-97.8	-227.2	-872	-97	-242.7	-1 000	-0.8	15.5	128
Rihand	Uttar Pradesh	93.75	-98	-208	1 454	-97.7	-237	-991.7	-0.3	29	2 445.7
Sarju	Uttar Pradesh	195.00	-96.7	-234	5 975	-100	-250	-1 000	3.3	16	6 975
Yamuna	Uttar Pradesh	208.76	-93.38	-220.88	40 825 494	-93.4	-228.65	-992.02	0.02	7.77	40 826 486
Baraker	West Bengal	250.00	-98.8	-250	69 000	-95.2	-226.7	-1 000	-3.6	-23.3	70 000
Damodar	West Bengal	125.86	-98.17	-233.6	251 179.6	-97.58	-214.4	-988.61	-0.59	-19.2	252 168.2
Ganga	West Bengal	51.49	-97.57	-225.58	339 337	-99	-233.25	-988.8	1.43	7.67	340 325.8
Roopnarayam	West Bengal	250.00	-98.4	-250	2 382 335	-98.9	-231.8	-988.61	0.5	-18.2	2 383 324

BOD – biochemical oxygen demand; COD – chemical oxygen demand; NA – not available; MPN – most probable number

Source Compiled by authors

Appendix 9

Change of water quality by state (by river) from acceptable limit over 1993–2003

			Difference 2003 (actual - acceptable)			*Difference 1993 (actual - acceptable)*			*Difference (2003 -1993)*		
River	*State*	*Volume* (km^3)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100 ml)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100 ml)	*BOD* (mg/l)	*COD* (mg/l)	*Total coliforms* (MPN/100 ml)
Godavari	Andhra Pradesh	40.16	5.2	5	3 198	2.27	9.1	0	2.93	-4.1	3 198
Krishna	Andhra Pradesh	15.98	1.96	31	9 617	1.85	9.1	7.3	0.11	21.9	9 609.7
Maner	Andhra Pradesh	6.81	2.45	10.5	149	1.8	6.7	0	0.65	3.8	149
Manjeera	Andhra Pradesh	4.87	2.7	16	32 192	2.3	8.1	0	0.4	7.9	32 192
Musi	Andhra Pradesh	5.54	11.65	94.2	892.5	7.8	27.6	0	3.85	66.6	892.5
Penner	Andhra Pradesh	6.16	2.75	15.5	781	4.9	24	0	-2.15	-8.5	781
Tungbhadra	Andhra Pradesh	9.26	2.15	13.4	0	2	7.1	0	0.15	6.3	0
Brahmaputra	Assam	18.29	1	13.08	571 565	1	9.35	8.46	0	3.73	571 556.5
Dhansari	Assam	6.78	1.5	9.6	56 460	12.4	9.22	16	-10.9	0.38	56 444
Gandak	Bihar	119.05	1.2	19	1 138	1.3	19.6	8.33	-0.1	-0.6	1 129.67
Ganga	Bihar	49.5	1.67	16.1	3 208	1.02	16.32	7.87	0.65	-0.22	3 200.13
Ghaghara	Bihar	23.15	1.4	19.5	2 013	1.9	22	6.22	-0.5	-2.5	2 006.78
Sone	Bihar	64.13	1.4	18.7	2 633	0.6	10.8	7.95	0.8	7.9	2 625.05
Hasdev	Chhattisgarh	13.11	2.1	26	290	5.3	66.45	4.2	-3.2	-40.45	285.8
Kharoon	Chhattisgarh	13.11	1.4	22.8	37	1.6	19.3	5.79	-0.2	3.5	31.21
Mahanadi	Chhattisgarh	20.97	1.8	30.35	66.33	3.2	14	4.59	-1.4	16.35	61.74
Seonath	Chhattisgarh	13.11	1.95	26.4	336	1.8	27.6	5.85	0.15	-1.2	330.15
Yamuna	Delhi	8.72	17.8	58	85 796 669	2.8	25.7	11	15	32.3	85 796 658
Mandovi	Goa	36.28	2.8	11	155	2.2	5.5	4.66	0.6	5.5	150.34
Zuari	Goa	36.28	2.3	11	163	2.6	5.7	4.7	-0.3	5.3	158.3
Damanganga	Gujarat	3.43	2.85	42	60.17	1.4	16.1	4	1.45	25.9	56.17
Khari	Gujarat	14.98	958.8	3 662.4	12 783 333	416	1 664	1.02	542.8	1 998.4	12 783 332
Mahi	Gujarat	1.29	1.14	13	45	1.9	13.9	7.6	-0.76	-0.9	37.4
Meshwa	Gujarat	13.34	1.9	8	7 508	2.2	18.1	11.4	-0.3	-10.1	7 496.6
Narmada	Gujarat	4.69	1.2	16.75	68.75	3	16	6.7	-1.8	0.75	62.05
Sabarmati	Gujarat	1.72	40	277	375 003.3	41	108	11	-1	169	374 992.3
Shedi	Gujarat	14.98	20.6	101.3	79 395	3	24.8	11.64	17.6	76.5	79 383.36
Tapi	Gujarat	4.29	1.93	3	574	3.3	22	8.5	-1.37	-19	565.5
Ghaggar	Haryana	23.43	9.3	78	0	9.6	31.3	4	-0.3	46.7	-4
Yamuna	Haryana	29.8	10.8	37.68	44 852 752	1.3	14.6	2.4	9.5	23.08	44 852 750
Bean	Himachal Pradesh	25.6	1.36	3.7	935	0.47	4.2	3.4	0.89	-0.5	931.6
Parvati	Himachal Pradesh	46	0.7	8	592	0.2	3	3.2	0.5	5	588.8
Ravi	Himachal Pradesh	10.09	0.75	2.5	40	0.4	6.4	3.95	0.35	-3.9	36.05
Satluj	Himachal Pradesh	NA	0.37	7.71	499	1.4	5.83	3.51	-1.03	1.88	495.49
Yamuna	Himachal Pradesh	2.73	3.4	42	137.5	0	0	0	3.4	42	137.5

			Difference 2003 (actual - acceptable)			Difference 1993 (actual - acceptable)			Difference (2003 -1993)		
River	State	Volume (km^3)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)
Subarnarekha	Jharkhand	4.64	1.87	31.75	1 042	2.9	6.3	8.5	-1.03	25.45	1 033.5
Bhadra	Karnataka	13.11	3.16	0	1 552	4.3	38	6.7	-1.14	-38	1 545.3
Bhima	Karnataka	16.73	1.6	22.66	6 979	1.4	45	7.3	0.2	-22.34	6 971.7
Cauvery	Karnataka	8.36	1.06	21.6	2 185	1	24.26	7.38	0.06	-2.66	2 177.62
Ghat Prabha	Karnataka	9.46	1.75	71.7	1 019	1.65	49.4	7.3	0.1	22.3	1 011.7
Kabbani	Karnataka	8.16	1.1	22	1 046	1.1	27	6.8	0	-5	1 039.2
Krishna	Karnataka	15.52	1.65	22.8	2 967	1.2	42.3	7.3	0.45	-19.5	2 959.7
Mal Prabha	Karnataka	12.57	1.46	27.16	1 406	1.4	52	7.3	0.06	-24.84	1 398.7
Shimsha	Karnataka	16.73	1.2	23	2 091	7	31	7.38	-5.8	-8	2 083.62
Tungbhadra	Karnataka	3.85	2.6	38	1 552	1.3	23.6	7.3	1.3	14.4	1 544.7
Achenkoil	Kerala	4.31	1.9	25.6	5 550	0.5	7.5	7.21	1.4	18.1	5 542.79
Bhavani	Kerala	0	0.3	3.2	875	0.4	6.7	7.72	-0.1	-3.5	867.28
Chaliyar	Kerala	16.73	0.45	8.4	1 450	0.45	8	7.69	0	0.4	1 442.31
Kabbani	Kerala	8.57	0.6	3.2	825	0.4	4.7	7	0.2	-1.5	818
Manimala	Kerala	16.73	0.7	14.4	3 062	0.4	6.8	7.6	0.3	7.6	3 054.4
Pamba	Kerala	16.73	1.1	20.8	14 866	0.7	8.1	7.3	0.4	12.7	14 858.7
Periyar	Kerala	16.73	1.4	6.4	390	5.3	8.3	7.3	-3.9	-1.9	382.7
Betwa	Madhya Pradesh	13.57	2.1	26	924	0	0	0	2.1	26	924
Chambal	Madhya Pradesh	9.56	2.77	11.92	636 198	8.5	60	6.01	-5.73	-48.08	636 192
Khan	Madhya Pradesh	NA	30	0	1 600	47.8	195.3	9.83	-17.8	-195.3	1 590.17
Kshipra	Madhya Pradesh	34.5	4.9	20	0	6.8	62.8	9.875	-1.9	-42.8	-9.875
Mahi	Madhya Pradesh	0.89	0	25	425	2.3	30.3	4.91	-2.3	-5.3	420.09
Mandakini	Madhya Pradesh	NA	6	0	345	2.8	41.3	4.46	3.2	-41.3	340.54
Narmada	Madhya Pradesh	28.89	1.82	21.4	179	2.5	22	5.3	-0.68	-0.6	173.7
Sone	Madhya Pradesh	185.87	1.6	18.7	666	2.2	44	3.8	-0.6	-25.3	662.2
Tapi	Madhya Pradesh	5.11	1.26	17.33	126.66	2	24	5.18	-0.74	-6.67	121.48
Tons	Madhya Pradesh	26.85	5.95	0	435.5	2.6	32	4.22	3.35	-32	431.28
Wainganga	Madhya Pradesh	26.4	2.25	20.5	292	5.2	38.5	5.4	-2.95	-18	286.6
Bhima	Maharashtra	30.55	16.18	24	278	5.2	24.85	4.2	10.98	-0.85	273.8
Girna	Maharashtra	36.28	6	5	254	5.1	24.5	4.3	0.9	-19.5	249.7
Godavari	Maharashtra	36.14	8.08	93	278	4.87	25.14	4.43	3.21	67.86	273.57
Krishna	Maharashtra	26.5	6.3	34	265	4.8	21.46	4.2	1.5	12.54	260.8
Nira	Maharashtra	36.28	6.5	0	228	4.9	56	4.4	1.6	-56	223.6
Patalganga	Maharashtra	NA	5.3	24	214	4.75	26.1	4.3	0.55	-2.1	209.7
Tapi	Maharashtra	5.11	5.9	4.66	231	5.3	26	4.2	0.6	-21.34	226.8
Ulhas	Maharashtra	36.28	5.7	32	218	4.55	22.4	4.2	1.15	9.6	213.8
Wainganga	Maharashtra	15.37	5.8	32	183	6.8	24.7	0	-1	7.3	183
Wardha	Maharashtra	36.28	5.2	0	173	5.6	26	4.43	-0.4	-26	168.57
Imphal	Manipur	NA	2.4	0	60	2.2	4.6	5.92	0.2	-4.6	54.08

Continued

Appendix 9 *Continued*

River	State	Volume (km^3)	Difference 2003 (actual - acceptable) BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Difference 1993 (actual - acceptable) BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)	Difference (2003 -1993) BOD (mg/l)	COD (mg/l)	Total coliforms (MPN/100 ml)
Dhamsiri	Nagaland	0	4.38	0	0	0	0	0	4.38	0	0
Baitarni	Orissa	17.73	1.66	0	4 437	4.36	22.56	5.92	-2.7	-22.56	4 431.08
Brahmani	Orissa	12.39	17	4.2	3 399	3.54	14.45	6.25	13.46	-10.25	3 392.75
I.B	Orissa	8.88	1.55	0	3 539	4.9	23.4	5.5	-3.35	-23.4	3 533.5
Kuakhai	Orissa	NA	2.25	0	4 779	3.6	14.6	6.15	-1.35	-14.6	4 772.85
Mahanadi	Orissa	29.02	1.86	24	5 706	4.1	19	5.8	-2.24	5	5 700.2
Nagavalli	Orissa	8.24	2.25	0	7 480	0	0	0	2.25	0	7 480
Rushikulya	Orissa	13.11	1.8	0	5 150	17.8	75	3.24	-16	-75	5 146.76
Subarnarekha	Orissa	1.07	1.7	2 330	0	0	0	0	1.7	2 330	0
Bean	Punjab	20.94	2.06	6.22	783	7.4	16.7	4.5	-5.34	-10.48	778.5
Ghaggar	Punjab	14.66	12	55	3 654	20	39	4	-8	16	3 650
Ravi	Punjab	5.05	12.8	25	2 944	0.8	1.9	3	12	23.1	2 941
Satluj	Punjab	NA	4.52	12.58	5 076	4.43	7.4	3.85	0.09	5.18	5 072.15
Chambal	Rajasthan	19.85	1.63	8.17	737	2.4	38	6.73	-0.77	-29.83	730.27
Mahi	Rajasthan	0.93	1.7	8.1	914	2.4	39.4	7.22	-0.7	-31.3	906.78
Testa	Sikkim	24	8.55	0	199	0	0	0	8.55	0	199
Bhavani	Tamil Nadu	16.73	1.6	13.8	1 243	15.27	43.5	11.1	-13.67	-29.7	1 231.9
Cauvery	Tamil Nadu	10.64	2.13	53.3	1 083	2.58	16.38	10.5	-0.45	36.92	1 072.5
Tambiraparami	Tamil Nadu	16.73	1.8	21.7	251	0	0	0	1.8	21.7	251
Betwa	Uttar Pradesh	20.93	2.1	27	1 100	2.2	17.7	12.26	-0.1	9.3	1 087.74
Chambal	Uttar Pradesh	5.09	2.2	11.9	2 542 583	2.8	15.3	1	-0.6	-3.4	2 542 582
Ganga	Uttar Pradesh	149.01	2.91	17.05	21 330	2.61	15	8.92	0.3	2.05	21 321.08
Ghaghara	Uttar Pradesh	108.8	1.3	21.05	1 120	3.2	8.1	8.43	-1.9	12.95	1 111.57
Gomti	Uttar Pradesh	250	2.5	15.5	18 798	5.03	19.76	9.52	-2.53	-4.26	18 788.48
Hindon	Uttar Pradesh	250	29.866	176	3 335 654	58	135	8.2	-28.134	41	3 335 646
Kalindi	Uttar Pradesh	NA	34.92	219	1.63E+08	3.9	27.2	12.26	31.02	191.8	1.63E+08
Ramganga	Uttar Pradesh	151.33	4.7	0	11 244	3.9	25.7	9.53	0.8	-25.7	11 234.47
Rapti	Uttar Pradesh	250	2.2	22.8	128	3	7.3	0	-0.8	15.5	128
Rihand	Uttar Pradesh	93.75	2	42	2 454	2.3	13	8.3	-0.3	29	2 445.7
Sarju	Uttar Pradesh	195	3.3	16	6 975	0	0	0	3.3	16	6 975
Yamuna	Uttar Pradesh	208.76	6.62	29.12	40 826 494	6.6	21.35	7.98	0.02	7.77	40 826 486
Baraker	West Bengal	250	1.2	0	70 000	4.8	23.3	0	-3.6	-23.3	70 000
Damodar	West Bengal	125.86	1.83	16.4	252 179.6	2.42	35.6	11.39	-0.59	-19.2	252 168.2
Ganga	West Bengal	51.49	2.43	24.42	340 337	1	16.75	11.2	1.43	7.67	340 325.8
Roopnarayam	West Bengal	250	1.6	0	2 383 335	1.1	18.2	11.39	0.5	-18.2	2 383 324

BOD –biochemical oxygen demand; COD – chemical oxygen demand; NA – not available; MPN – most probable number

Source Compiled by authors

Appendix 10

Cost of treatment for representative plants

Treatment plant costs: Both plants treat 56 million litres of water per day

This is equal to 20 440 000 m^3 per year. Details of the Ghaziabad plant's cost of treatment is given below.

Ghaziabad

Item		*USAB*	*ASP*	*TF*	*OP*
1a)	Unit land requirement (acre/mld)	0.42	0.5	0.5	2.5
1b)	Actual requirement (acre)	23.52	28	28	140
1c)	Land cost @ Rs 13.10 (lakh per acre)	308.11	366.8	366.8	1834
1d)	Land cost per m^3 treated Rs lakh	1.50E-05	1.79E-05	1.79E-05	8.97E-05
2a)	Unit cost of plant (Rs lakh/MLD)	24.44	29.5	28.5	7
2b)	Unit cost of Plant (Rs lakh/m^3)	6.78E-05	8.08E-05	7.80E-05	1.48E-05
2c)	Cost of plant (Rs lakh)	1 386.64	1 652	1 596	302
3a)	Unit O&M (operation and maintenance) cost/MLD/year (Rs lakh)	0.51	1	0.75	0.4
3b)	Unit O&M cost/m^3/year (Rs lakh)	1.40E-06	2.82E-06	2.05E-06	1.10E-06
3c)	O&M cost/year (Rs lakh)	28.56	57.68	42	22.4
3di)	Resource recovery per MLD/year (Rs lakh)	0.4	0.3	0.25	0.1
3dii)	Resource recovery per m^3/year (Rs lakh)				
3diii)	Per year (Rs lakh)				
3ei)	Net O&M per MLD/year (Rs lakh)	0.11	0.73	0.5	0.3
3eii)	Per m^3 per year (Rs lakh)	3.01E-07	0.00	0.00	8.22E-07
3eiii)	Per year (Rs lakh)	6.16	40.88	28	16.8
4)	Capitalized O&M cost for 20 years @ 12%				
4a)	Rs lakh/MLD	0.82	5.45	3.74	2.24
4b)	Rs lakh /m^3	2.25E-06	1.495E-05	1.025E-05	6.14E-06
4c)	Total O&M in 20 years (Rs lakh)	45.92	305.2	209.44	125.5
Total cost of project (Rs lakh)					
5a)	With resource recovery	1 740.67	2 324	2 172.24	2 261.5
5ai)	Total cost with resource recovery/m^3 (Rs)	8.52	11.37	10.63	11.06
5b)	Without resource recovery				
5bi)	Total cost wihout resource recovery/m^3				
Assuming costs spread over 20 years					
Land cost (Rs lakh)		15.41	18.34	18.34	91.7
Plant cost (Rs lakh)		69.33	82.6	79.8	15.1
O&M Rs (lakh)		45.92	305.2	209.44	125.5
New total over 20 years resource recovery/m^3 (Rs)		0.64	1.99	1.50	1.14

MLD – million litres per day; O&M – operation and maintenance; UASB – upflow anaerobic sludge blanket; ASP – activated sludge process; TF – trickling filter; OP – oxidation pond; m^3 – cubic metre

Source CPCB (2004 b)

Appendix 11 Reduction in heavy (toxic) metals in sewage treatment plants, Delhi

Name of plant	Concentration of metals in influent								Concentration of metals in effluent							
	Cd	*Cr*	*Cu*	*Fe*	*Ni*	*Pb*	*Zn*	*Total Hg*	*Cd*	*Cr*	*Cu*	*Fe*	*Ni*	*Pb*	*Zn*	*Total Hg*
Najafgarh	0.01	NT	NT	3.22	NT	NT	0.15	NT	NT	NT	NT	0.35	NT	NT	NT	NT
Papankala	0.01	NT	NT	0.24	NT	NT	0.05	ND	NT	NT	NT	NT	NT	NT	NT	ND
Delhi Gate	NT	17	0.45	3.46	0.01	NT	0.65	NT	0.01	NT	NT	0.76	NT	NT	0.06	NT
Dr Sen NH	0.01	NT	0.04	2.56	NT	NT	0.28	NT	NT	NT	NT	0.28	NT	NT	0.03	NT
Nilothi	NT	0.27	0.11	7.1	0.04	NT	0.63	NT	NT	NT	NT	0.24	NT	NT	0.05	NT
Cor. Pillar	0.01	NT	0.29	0.91	NT	NT	0.08	ND	NT	NT	0.86	0.38	NT	0.02	0.01	ND
Cor. Pillar	NT	7.6	2.53	79.9	0.63	NT	0.28	NT	NT	0.17	0.36	6.5	0.32	NT	0.02	NT
Timarpur	0.01	7.3	1.69	61.9	0.47	NT	0.32	NT	0.01	NT	NT	0.83	0.04	NT	NT	NT
Narela	0.01	NT	0.05	6.7	NT	NT	0.76	NT	NT	NT	NT	0.48	NT	NT	1.33	NT
Vasant Kunj	NT	NT	NT	1.91	NT	NT	0.25	NT	NT	NT	NT	0.32	NT	NT	0.03	NT
Vasant Kunj	NT	NT	NT	2.62	NT	NT	0.31	NT	0.01	NT	NT	0.19	NT	NT	0.04	NT
Okhla	NT	NT	0.03	3.84	0.02	NT	0.3	NT	NT	NT	NT	0.7	NT	NT	0.23	NT
Okhla	NT	NT	0.03	5.09	NT	0.02	0.34	NT	0.01	NT	NT	0.07	NT	NT	0.02	NT
Okhla	0.01	NT	NT	3.18	NT	NT	0.28	NT	0.01	NT	NT	0.31	NT	NT	0.07	NT
Okhla	NT	NT	NT	2.45	NT	NT	0.27	NT	NT	NT	NT	0.08	NT	NT	0.04	NT
Okhla	NT	NT	NT	2.45	NT	NT	0.27	NT	NT	NT	NT	0.34	NT	NT	0.02	NT
Yamuna Vihar	NT	NT	0.1	2.27	0.01	NT	0.40	NT	0.01	NT	NT	0.19	NT	NT	0.07	NT
Yamuna Vihar	0.01	NT	0.22	2.63	NT	1.1	0.50	NT	NT	NT	NT	0.28	NT	NT	0.14	NT
Keshopur	0.01	NT	0.06	4.59	NT	0.1	0.68	NT	NT	NT	NT	0.56	NT	NT	0.15	NT
Keshopur	0.01	NT	0.06	4.59	NT	0.1	0.68	NT	NT	NT	NT	0.06	NT	NT	0.04	NT
Kondali	NT	NT	0.06	1.59	0.03	NT	0.38	NT	NT	NT	NT	0.33	NT	NT	0.08	NT
Kondali	NT	NT	0.02	3.43	NT	NT	0.23	NT	NT	NT	NT	0.1	NT	NT	0.09	NT
Kondali	–	–	–	–	–	–	–	NT	NT	NT	NT	0.33	NT	NT	0.04	NT
Rithala	NT	NT	0.06	2.82	NT	NT	0.32	NT	NT	NT	NT	0.8	NT	NT	0.1	NT
Rithala	–	–	–	–	–	–	–	NT	NT	NT	NT	0.25	NT	NT	0.04	NT
Mehrauli	NT	NT	0.01	8.7	0.05	NT	0.50	NT	NT	NT	NT	0.11	NT	NT	0.03	NT

All values in mg/litre. NT – not traceable; ND – not done; Cd – cadmium; Cr – chromium; Cu – copper; Fe – iron; Ni – nickel; Pb – lead; Zn – zinc; Hg – mercury

Source CPCB (2004 a, b)

Green Accounting for Indian States and Union Territories Project

In common with most developing nations, India faces many trade-offs in its attempt to improve the living standards of its people. The trade-offs emerge in various arenas, and several mechanisms for decision-making (including political institutions) have been developed to help choose between competing alternatives. Unfortunately, most of these decision mechanisms do not take into account intergenerational choices, i.e. trade-offs between the needs of the present and the future generations. In our view, it is urgently necessary to develop a mechanism to do this because many of the choices we make today could severely affect the welfare of our children tomorrow.

Therefore, we propose to build a framework of national accounts that presents genuine net additions to national wealth. This system of environmentally-adjusted national income accounts will not only account for the depletion of natural resources and the costs of pollution but also reward additions to the stock of human capital.

The Green Accounting for Indian States and Union Territories Project (GAISP) aims to set up economic models for preparing annual estimates of 'genuine savings', i.e. true 'value addition', at both state and national levels. The publication of the results will enable policy-makers and the public to engage in a debate on the sustainability of growth as well as make cross-state comparisons. It is hoped that a policy consequence of the project is gradual increases in budgetary allocations for improvements in education, public health, and environmental conservation, all of which are key elements needed to secure India's long-term future.

Monograph 8

This monograph is part of a larger effort to build, for India, an empirically based framework of 'green accounting' that would allow decision-makers to develop effective strategic responses to the depletion and accumulation of natural and human capital. In this monograph, we have attempted to adjust national and state accounts for the degradation in water quality over a ten-year period. We have specifically considered the quality changes in groundwater and surface water. The effort is to organize the complex database of water in India and analyse the trend in its quality over a period of time. The quality of water has been judged on well-accepted criteria suggested by government agencies. By adopting a replacement cost approach, the monetary value of the decline in water quality for each use has been estimated. This decline in quality has been treated in the same way as depreciation of man-made capital and has been adjusted against the state domestic products for each of India's states. This monograph should also be seen as an attempt to organize the complexities of information in the country's water sector. Of course, we recognize that the results need to be treated with caution due to data limitations and the difficulties with incorporating water quality data into the SEEA (System of Environment and Economic Accounting) framework.

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