Water Pollution Control - A Guide to the Use of Water Quality Management Principles
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Case Study I* - The Ganga, India

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I.1 Introduction

There is a universal reverence to water in almost all of the major religions of the world. Most religious beliefs involve some ceremonial use of "holy" water. The purity of such water, the belief in its known historical and unknown mythological origins, and the inaccessibility of remote sources, elevate its importance even further. In India, the water of the river Ganga is treated with such reverence.

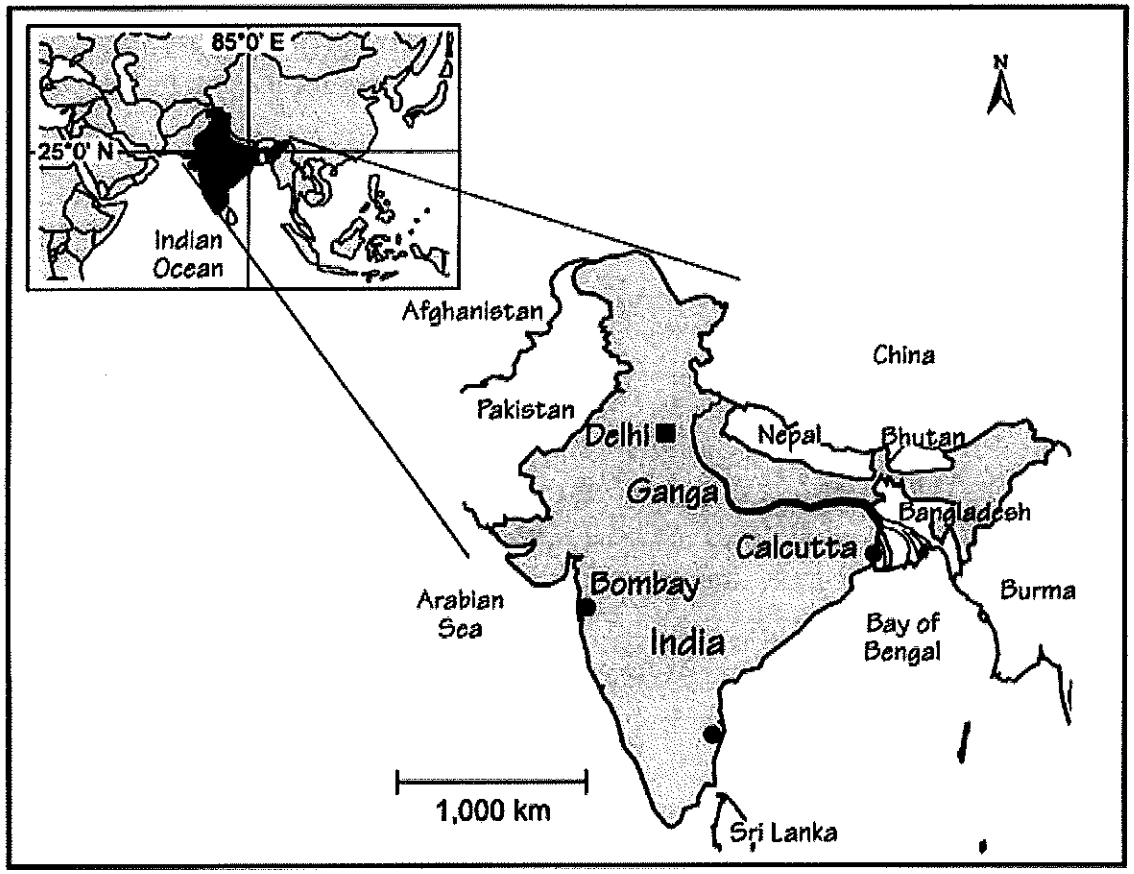
The river Ganga occupies a unique position in the cultural ethos of India. Legend says that the river has descended from Heaven on earth as a result of the long and arduous prayers of King Bhagirathi for the salvation of his deceased ancestors. From times immemorial, the Ganga has been India's river of faith, devotion and worship. Millions of Hindus accept its water as sacred. Even today, people carry treasured Ganga water all over India and abroad because it is "holy" water and known for its "curative" properties. However, the river is not just a legend, it is also a life-support system for the people of India. It is important because:

- The densely populated Ganga basin is inhabited by 37 per cent of India's population.
- The entire Ganga basin system effectively drains eight states of India.
- About 47 per cent of the total irrigated area in India is located in the Ganga basin alone.
- It has been a major source of navigation and communication since ancient times.
- The Indo-Gangetic plain has witnessed the blossoming of India's great creative talent.

I.2 The Ganga river

The Ganga rises on the southern slopes of the Himalayan ranges (Figure I.1) from the Gangotri glacier at 4,000 m above mean sea level. It flows swiftly for 250 km in the mountains, descending steeply to an elevation of 288 m above mean sea level. In the Himalayan region the Bhagirathi is joined by the tributaries Alaknanda and Mandakini to form the Ganga. After entering the plains at Hardiwar, it winds its way to the Bay of Bengal, covering 2,500 km through the provinces of Uttar Pradesh, Bihar and West Bengal (Figure I.2). In the plains it is joined by Ramganga, Yamuna, Sai, Gomti, Ghaghara, Sone, Gandak, Kosi and Damodar along with many other smaller rivers.

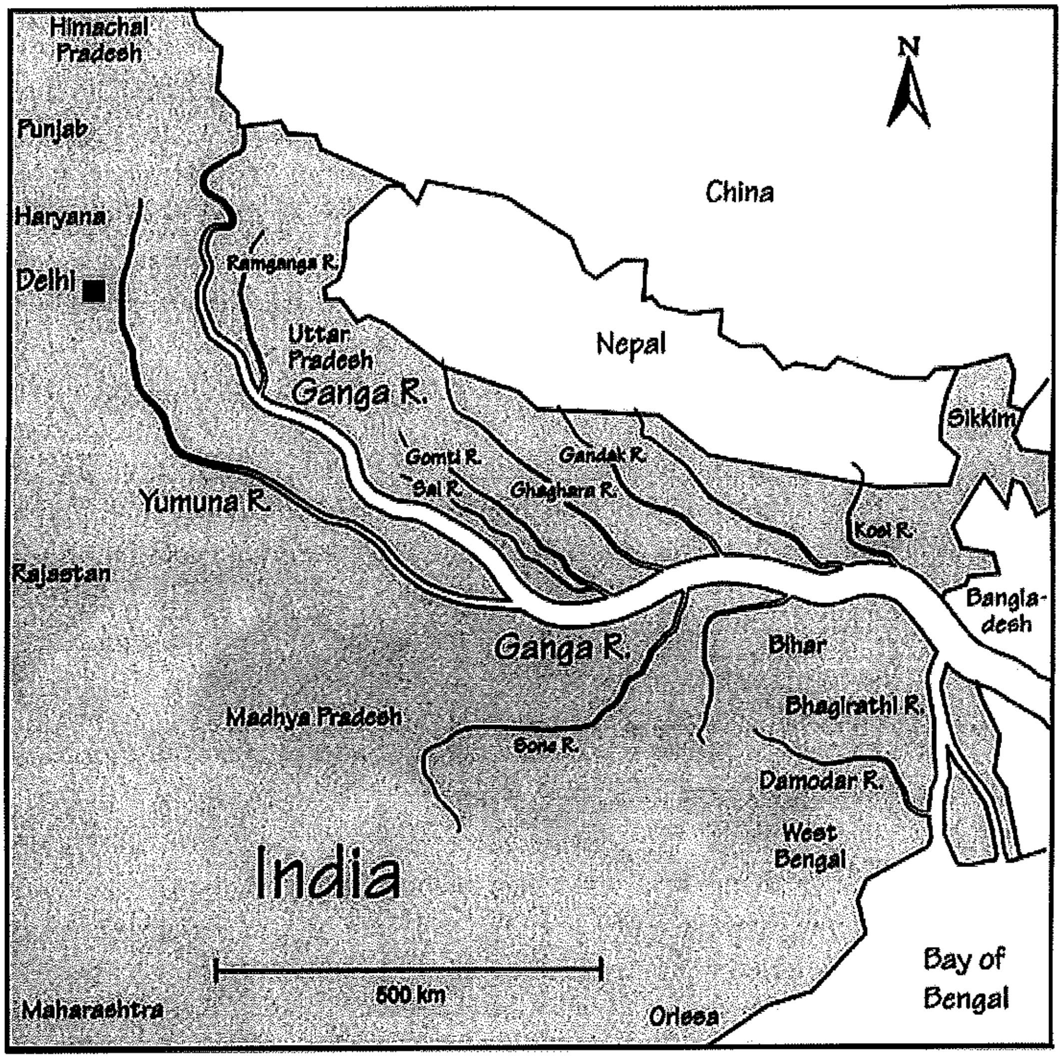
Figure I.1 Location map of India showing the Ganga river



The purity of the water depends on the velocity and the dilution capacity of the river. A large part of the flow of the Ganga is abstracted for irrigation just as it enters the plains at Hardiwar. From there it flows as a trickle for a few hundred kilometres until Allahabad, from where it is recharged by its tributaries. The Ganga receives over 60 per cent of its discharge from its tributaries. The contribution of most of the tributaries to the pollution load is small, except from the Gomti, Damador and Yamuna rivers, for which separate action programmes have already started under Phase II of "The National Rivers Conservation Plan".

The Ganga river carries the highest silt load of any river in the world and the deposition of this material in the delta region results in the largest river delta in the world (400 km from north to south and 320 km from east to west). The rich mangrove forests of the Gangetic delta contain very rare and valuable species of plants and animals and are unparalleled among many forest ecosystems.

Figure I.2 Map of India showing the route of the Ganga river



I.2.1 Exploitation

In the recent past, due to rapid progress in communications and commerce, there has been a swift increase in the urban areas along the river Ganga, As a result the river is no longer only a source of water but is also a channel, receiving and transporting urban wastes away from the towns. Today, one third of the country's urban population lives in the towns of the Ganga basin. Out of the 2,300 towns in the country, 692 are located in this basin, and of these, 100 are located along the river bank itself.

The belief the Ganga river is "holy" has not, however, prevented over-use, abuse and pollution of the river. All the towns along its length contribute to the pollution load. It has been assessed that more than 80 per cent of the total pollution load (in terms of organic pollution expressed as biochemical oxygen demand (BOD)) arises from domestic sources, i.e. from the settlements along the river course. Due to over-abstraction of water for irrigation in the upper regions of the river, the dry weather flow has been reduced to a trickle. Rampant deforestation in the last few decades, resulting in topsoil erosion in the catchment area, has increased silt deposits which, in turn, raise the river bed and lead to devastating floods in the rainy season and stagnant flow in the dry season. Along the main river course there are 25 towns with a population of more than 100,000 and about another 23 towns with populations above 50,000. In addition there are 50 smaller towns with populations above 20,000. There are also about 100 identified major industries located directly on the river, of which 68 are considered as grossly polluting. Fifty-five of these industrial units have complied with the regulations and installed effluent treatment plants (ETPs) and legal proceedings are in progress for the remaining units. The natural assimilative capacity of the river is severely stressed.

The principal sources of pollution of the Ganga river can be characterised as follows:

• Domestic and industrial wastes. It has been estimated that about $1.4 \times 10^6 m^3 d^{-1}$ of domestic wastewater and $0.26 \times 10^6 m^3 d^{-1}$ of industrial sewage are going into the river.

• Solid garbage thrown directly into the river.

• Non-point sources of pollution from agricultural run-off containing residues of harmful pesticides and fertilisers.

• Animal carcasses and half-burned and unburned human corpses thrown into the river.

• Defecation on the banks by the low-income people.

• Mass bathing and ritualistic practices.

I.3 The Ganga Action Plan

I.3.1 Scientific awareness

There are 14 major river basins in India with natural waters that are being used for human and developmental activities. These activities contribute significantly to the pollution loads of these river basins. Of these river basins the Ganga sustains the largest population. The Central Pollution Control Board (CPCB), which is India's national body for monitoring environmental pollution, undertook a comprehensive scientific survey in 1981-82 in order to classify river waters according to their designated best uses. This report was the first systematic document that formed the basis of the Ganga Action Plan (GAP). It detailed land-use patterns, domestic and industrial pollution loads, fertiliser and pesticide use, hydrological aspects and river classifications. This inventory of pollution was used by the Department of Environment in 1984 when formulating a policy document. Realising the need for urgent intervention the Central Ganga Authority (CGA) was set up in 1985 under the chairmanship of the Prime Minister.

The Ganga Project Directorate (GPD) was established in June 1985 as a national body operating within the National Ministry of Environment and Forest. The GPD was intended to serve as the secretariat to the CGA and also as the Apex Nodal Agency for implementation. It was set up to co-ordinate the different ministries involved and to administer funds for this 100 per cent centrally-sponsored plan. The programme was perceived as a once-off investment providing demonstrable effects on river water quality. The execution of the works and the subsequent operation and management (O&M) were the responsibility of the state governments, under the supervision of the GPD. The GPD was to remain in place until the GAP was completed. The plan was formally launched on 14 June 1986. The main thrust was to intercept and divert the wastes from urban settlements away from the river. Treatment and economical use of waste, as a means of assisting resource recovery, were made an integral part of the plan.

It was realised that comprehensive co-ordinated research would have to be conducted on the following aspects of Ganga:

- The sources and nature of the pollution.

- A more rational plan for the use of the resources of the Ganga for agriculture, animal husbandry, fisheries, forests, etc.

- The demographic, cultural and human settlements on the banks of the river.

- The possible revival of the inland water transport facilities of the Ganga, together with the tributaries and distributaries.

One outcome of this initiative was a multi-disciplinary study of the river in which the 14 universities located in the basin participated in a well co-ordinated, integrated research programme. This was one of largest endeavours, involving several hundred scientists, ever undertaken in the country and was funded under the GAP. The resultant report is a unique, integrated profile of the river.

The GAP was only the first step in river water quality management. Its mandate was limited to quick and effective, but sustainable, interventions to contain the damage. The studies carried out by the CPCB in 1981-82 revealed that pollution of the Ganga was increasing but had not assumed serious proportions, except at certain main towns on the river such as industrial Kanpur and Calcutta on the Hoogly, together with a few other towns. These locations were identified and designated as the "hot-spots" where urgent interventions were warranted. The causative factors responsible for these situations were targeted for swift and effective control measures. This strategy was adopted for urgent implementation during the first phase of the plan under which only 25 towns identified on the main river were to be included. The studies had revealed that:

- 75 per cent of the pollution load was from untreated municipal sewage.

- 88 per cent of the municipal sewage was from the 25 Class I towns on the main river.

- Only a few of these cities had sewage treatment facilities (these were very inadequate and were often not functional).

- All the industries accounted for only 25 per cent of the total pollution (in some areas, such as Calcutta and Kanpur, the industrial waste was very toxic and hard to treat).

I.3.2 Attainable objectives

The broad aim of the GAP was to reduce pollution and to clean the river and to restore water quality at least to Class B (i.e. bathing quality: 3 mg l^{-1} BOD and 5 mg l^{-1} dissolved oxygen). This was considered as a feasible objective and because a unique and distinguishing feature of the Ganga was its widespread use for ritualistic mass bathing. The other environmental benefits envisaged were improvements in, for example, fisheries, aquatic flora and fauna, aesthetic quality, health issues and levels of contamination.

The multi-pronged objectives were to improve the water quality, as an immediate short-term measure, by controlling municipal and industrial wastes. The long-term objectives were to improve the environmental conditions along the river by suitably reducing all the polluting influences at source. These included not only the creation of waste treatment facilities but also invoking remedial legislation to control such non-point sources as agricultural run-off containing residues of fertilisers and pesticides, which are harmful for the aquatic flora and fauna. Prior to the creation of the GAP, the responsibilities for pollution of the river were not clearly demarcated between the various government agencies. The pollutants reaching the Ganga from most point sources did not mix well in the river, due to the sluggish water currents, and as a result such pollution often lingered along the embankments where people bathed and took water for domestic use.

I.3.3 The strategy

The GAP had a multi-pronged strategy to improve the river water quality. It was fully financed by the central Government, with the assets created by the central Government to be used and maintained by the state governments. The main thrust of the plan was targeted to control all municipal and industrial wastes. All possible point and non-point sources of pollution were identified. The control of point sources of urban municipal wastes for the 25 Class I towns on the main river was initiated from the 100 per cent centrally-invested project funds. The control of urban non-point sources was also tackled by direct interventions from project funds. The control of non-point source agricultural run-off was undertaken in a phased manner by the Ministry of Agriculture, principally by reducing use of fertiliser and pesticides. The control of point sources of industrial wastes was done by applying the polluter-pays-principle.

A total of 261 sub-projects were sought for implementation in 25 Class I (population above 100,000) river front towns. This would eventually involve a financial outlay of Rs 4,680 million (Indian Rupees), equivalent to about US$ 156 million. More than 95 per cent of the programme has been completed and the remaining sub-projects are in various stages of completion. The resultant improvement in the river water quality, although noticeable, is hotly debated in the media by certain non-governmental organisations (NGOs). The success of the programme can be gauged by the fact that Phase II of the plan, covering some of the tributaries, has already been launched by the Government. In addition, the earlier action plan has now evolved further to cover all the other major national river-basins in India, including a few lakes, and is known as the "National Rivers Conservation Plan".

Domestic waste

The major problem of pollution from domestic municipal sewage ($1.34 \times 10^6 m^3 d^{-1}$) arising from the 25 selected towns was handled directly by financing the creation of facilities for interception, diversion and treatment of the wastewater, and also by preventing the other city wastes from entering the river. Out of the $1.34 \times 10^6 m^3 d^{-1}$ of sewage assessed to be generated, $0.873 \times 10^6 m^3 d^{-1}$ was intercepted by laying 370 km of trunk sewers with 129 pumping stations as part of 88 sub-projects. The laying of sewers and the renovation of old sewerage was restricted only to that required to trap the existing surface drains flowing into the river. Facilities for solid waste collection using mechanised equipment and sanitary landfill, low-cost toilet complexes (2,760 complexes), partly-subsidised individual pour flush toilets (48,000), 28 electric crematoriums for human corpses, and 35 schemes of river front development for safer ritualistic bathing, were also included. A total of 261 such projects were carried out in the 25 towns. The programme also included 35 modern sewage treatment plants. The activities of the various sub-projects can be summarised as follows:

Approach to river water quality improvement	Number of schemes
Interception and diversion of municipal wastewater	88
Sewage treatment plants	35
Low-cost sanitation complexes	43
Electric crematoriums	28
River front facilities for bathing	35
Others (e.g. biological conservation of aquatic species, river quality monitoring)	32
Total	261

A total of 248 of these schemes have already been commissioned and those remaining are due to be completed by 1998.

Industrial waste

About 100 industries were identified on the main river itself. Sixty-eight of these were considered grossly polluting and were discharging $260 \times 10^3 m^3 d^{-1}$ of wastewater into the river. Under the Water (Prevention and Control of Pollution) Act 1974 and Environment (Protection) Act 1986, 55 industrial units (generating $232 \times 10^3 m^3 d^{-1}$) out of the total of 68 (identified) grossly polluting industrial units complied and installed effluent treatment plants. In addition, two others have treatment plants under construction and currently one unit does not have a treatment plant. Legal proceedings have been taken against the remaining 12 industrial units which were closed down for non-compliance.

Integrated improvements of urban environments

Apart from the above, the GAP also covered very wide and diverse activities, such as conservation of aquatic species (gangetic dolphin), protection of natural habitats (scavenger turtles) and creating riverine sanctuaries (fisheries). It also included components for landscaping river frontage (35 schemes), building stepped terraces on the sloped river banks for ritualistic mass-bathing (128 locations), improving sanitation along the river frontage (2,760 complexes), development of public facilities, improved approach roads and lighting on the river frontage.

Applied research

The Action Plan stressed the importance of applied research projects and many universities and reputable organisations were supported with grants for projects carrying out studies and observations which would have a direct bearing on the Action Plan. Some of the prominent subjects were PC-based software modelling, sewage-fed pisciculture, conservation of fish in upper river reaches, bioconservation in Bihar, monitoring of pesticides, using treated sewage for irrigation, and rehabilitation of turtles.

Some of the ongoing research projects include land application of untreated sewage for tree plantations, aquaculture for sewage treatment, disinfection of treated sewage by ultra violet radiation, and disinfection of treated sewage by Gamma radiation. Expert advice is constantly sought by involving regional universities in project formulation and as consultants to the implementing agencies to keep them in touch with the latest technologies. Eight research projects have been completed and 17 are ongoing. All the presently available research results are being consolidated for easy access by creation of a data base by the Indian National Scientific Documentation Centre (INSDOC).

Public participation

The pollution of the river, although classified as environmental, was the direct outcome of a deeper social problem emerging from long-term public indifference, diffidence and apathy, and a lack of public awareness, education and social values, and above all from poverty.

In recognition of the necessity of the involvement of the people for the sustainability and success of the Action Plan, due importance was given to generating awareness through intensive publicity campaigns using the press and electronic media, audio visual approaches, leaflets and hoardings, as well as organising public programmes for spreading the message effectively. In spite of full financial support from the project, and in spite of a heavy involvement of about 39 well known NGOs to organise these activities, the programme had only limited public impact and even received some criticism. Other similar awareness-generating programmes involving school children from many schools in the project towns were received with greater enthusiasm. These efforts to induce a change in social behaviour are meandering sluggishly like the Ganga itself.

Technology options

The choice of technology for the GAP was largely conventional, based on available options and local considerations. Consequently, the sewers and pumping stations and all similar municipal and conservancy works were executed in each province by its own implementing agencies, according to their customary practices but within the commonly prescribed specifications, fiscal controls and time frames. The choice of technology for most of the large domestic wastewater treatment plants was carefully decided by a panel of experts, in close consultation with those external aid agencies which were supporting that particular project. A parallel procedure was adopted in-house for all other similar projects. For all the larger sewage treatment plants the unanimous choice was to adopt the well-accepted activated sludge process. For other plants trickling filters were considered more appropriate. In smaller towns where land was available and the quantity of wastewater was small, other options such as oxidation ponds were chosen. However, unconventional technologies like the rope bound rotating biological contactors (RBRC), sewage irrigated afforestation, upflow anaerobic sludge blanket (UASB) technology and plants for chromium recovery from tannery waste-water were tried out with a fair degree of success. Some of these new and simpler technologies, with their low-cost advantages, will emerge as the large-scale future solution to India's sanitation problems.

Operation and maintenance

The enduring success of the pollution abatement works under the GAP is essential for sustainability. Most of these works were carried out by the same agencies which were eventually responsible for maintaining them as part of their primary functions, such as the city development authority, the municipality, or the irrigation and flood control department. The responsibility for subsequent O&M of these works automatically passed to these agencies. The most crucial components for preventing river pollution were the main pumping stations which were intercepting the sewage and diverting it to the treatment plants. These large capacity pumping stations, operating at the city level, had been built for the first time in India, and it was considered unlikely that the municipalities would have adequate resources and skilled personnel to be able to manage them. An integral part of the earlier planning of these sewage treatment works had been self sufficiency from resource recovery by the sale of treated effluent as irrigation water for agriculture, by the sale of dried sludge as manure (because it was rich in nutrients) and from the generation of electricity from the bio-gas production in the plant. It was considered that the generation of bio-electricity would be sufficient to offset much of the cost of the huge energy inputs required. In time it was realised that all these assumptions were only partly true. The state governments took over the responsibility of O&M through the same agencies that had built the plants by providing the funds to cover the deficit of the O&M expenditures. The central Government shared half of this deficit until 1997. In the broader interest of pollution control, future policies will also be similar, where the state governments undertake the responsibility for pollution control works because the local bodies are unable to bear the cost of the O&M expenditures with such limited resources.

I.4 Implementation problems

The implementation of a project of this magnitude over the entire 2,500 km stretch of the river, covering 25 towns and crossing three different provinces, could only be achieved by delegating the actual implementation to the state government agencies which had the appropriate capabilities. The state governments also undertook the responsibility of subsequently operating and maintaining the assets being created under the programme. The overall inter-agency co-ordination was done by the GPD through the state governments. The defined project objectives were ensured by the GPD through appraisal of each project component submitted by the implementing agency. The overall fiscal control was exercised by the GPD by close professional monitoring of the physical progress through independent agencies.

The progress in the first four years was satisfactory. The swift commissioning of the interception and diversion works as an immediate priority, ensured that most of the city wastes were collected and re-released to the river downstream of the city, thus earning public approval for the remarkably clean city waterfronts. However, some of the major sewage treatment plants (STPs) could not be completed in the original time frame. The delays in the completion of these major plants were unavoidable because treatment plants of such large capacity for domestic wastewater were being built for the first time in the country. The involvement of the external aid agencies was initially useful in introducing new technologies, such as chrome recovery plants for tannery wastewaters, low energy input technologies like the UASB and *in situ* sewer rehabilitation technology. However, the involvement of aid agencies, with their associated mandatory procedures, also added to the complexities of decision-making, especially in the large STP projects. The aid was awarded on a turn-key basis by inviting global bids. On account of the huge capital outlay, the final approvals were a multi-stage process and sometimes quite removed from the actual execution level. The collective wisdom of many experts was at times at odds with the opinions of the executing agency officials, who had to take the final responsibility. The procedural delays experienced with mid-project decisions on some issues of these turn-key contracts gave the contractors grounds to justify their own shortcomings in causing the original delays. Therefore, project schedules had to be relaxed several times. Of the original 261 sub-projects, 95 per cent are now complete and functioning satisfactorily. The remaining projects are mainly STPs and are in progress, due to be completed by 1998.

I.5 River water quality monitoring

Right from its inception in 1986, the GAP started a very comprehensive water quality monitoring programme by obtaining data from 27 monitoring stations. Most of these river water quality monitoring stations already existed under other programmes and only required strengthening. Technical help was also received for a small part of this programme from the Overseas Development Agency (ODA) of the UK in the form of some automatic water quality monitoring stations, the associated modelling software, training and some hardware. The monitoring programme is being run on a permanent basis using the infrastructure of other agencies such as the CPCB and the Central Water Commission (CWC) to monitor data from 16 stations. Some research institutions like the Industrial Toxicology Research Centre (ITRC) are also included for specialised monitoring of toxic substances. The success of the programme is noticeable through this record of the water quality over the years, considered in proportion to the number of improvement schemes commissioned. To evaluate the results of this programme an independent study of water quality has also been awarded to separate universities for different regional stretches of the river.

I.6 The future

Apart from the visible improvement in the water quality, the awareness generated by the project is an indicator of its success. It has resulted in the expansion of the programme over the entire Ganga basin to cover the other polluted tributaries. The GAP has further evolved to cover all the polluted stretches of the major national rivers, and including a few lakes. Considering the huge costs involved the central and state governments have agreed in principle to each share half of the costs of the projects under the "National Rivers Action Plan". The state governments are also required to organise funds for sustainable O&M in perpetuity. Initially, the plan was fully sponsored by the central Government.

I.7 Conclusions and lessons learned

The GAP is a successful example of timely action due to environmental awareness at the governmental level. Even more than this, it exhibits the achievement potential which is attainable by "political will". It is a model which is constantly being upgraded and improved in other river pollution prevention projects. Nevertheless, some very important lessons have been learned which are being incorporated into further projects. These include lessons learned about poor resource recovery due to poor resource generation, because of the lower organic content of Indian sewage. This may be due to less nutritious dietary habits, higher water consumption, fewer sewer connections, higher grit loads, insufficient flows and stagnation leading to bio-degradation of the volatile fractions in the pipes themselves. The assumed BOD design load of the plants were, in some cases, considered much higher than the actual BOD loading. This was due to a lack of practical experience within India and the fact that western experiences were not entirely appropriate.

There were also many lessons learned associated with the project objectives, which overlapped in many areas with urban infrastructure development, especially when the GAP was mistakenly assumed to be a city improvement plan. This led to an initial rise in general expectations followed by disappointments when the GAP was found to limit itself only to river pollution abatement without pursuing popular measures. This could have been one of the main reasons why it attracted some sharp criticism. In spite of close co-ordination with the Ministry of Urban Development at the central and state government levels, this communication gap still remains because future planning is still based on narrow considerations and short-term objectives (solely due to resource constraints), without addressing the root causes, which were also being overlooked earlier for precisely the same reasons. Thus the river pollution plan being "action" orientated, avoids involvement in long-term town planning, which continues to remain deficient with respect to environmental sanitation. This is due to a lack of overview by any stakeholding agency and to the blinkered foresight by the already beleaguered city authorities who remain perpetually short of funds for their daily crisis-management.

The most important lesson learned was the need for control of pathogenic contamination in treated effluent. This could not be tackled before because of a lack of safe and suitable technology but is now being attempted through research and by developing a suitable indigenous technology, which should not impart traces of any harmful residues in the treated effluent detrimental to the aquatic life. This is an aspect difficult to control in surface waters in tropical areas, but it is very important for the Ganga because the river water is used directly by millions of devout individuals for drinking and bathing.

I.8 Recommendations

The Action Plan started as a "cleanliness drive" and continues in the same noble spirit with the same zeal and enthusiasm on other major rivers and freshwater bodies. Its effectiveness could however be enhanced if these efforts could be integrated and well-accepted within the long-term objectives and master plans of the cities, which are constantly under preparation without adequate attention to the disposal of wastes. More information on polluted groundwater resources in the respective river basins will prove useful, because the existing levels of depletion and contamination of groundwater resources, which are already overexploited and fairly contaminated, will increase the dependency in the future on the rivers, as the only economical source of drinking water. This aspect has not been seriously considered in any long-term planning.

I.9 Source literature

This chapter was prepared from publicity material issued by the Ganga Project Directorate, New Delhi.