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Sustainable Development and River Cleaning: Cost Benefit Analysis of Cleaning Ganges*

INTRODUCTION

Rivers are important life supporting systems on earth, providing a variety of ecological services. They are part of wetland ecosystems supplying fresh water for household, agricultural, and industrial uses through surface flows and ground water recharges, and fish for household consumption. The rivers are sources for hydro power, navigation, and scenic beauty and they also support aquatic life and bio-diversity. They are also waste receptors from anthropogenic activities, an ecological function bringing to the forefront the issue of trade-off between the conservation of river systems and economic development. River as an environment resource has a natural regenerative property assimilating certain loads of pollution from households, industry, and agriculture. The pollution loads in excess of the assimilative capacity of the river could affect all of its ecological services. Therefore, the environmentally sustainable use of a river system requires its cleaning. The experiences of cleaning programmes of some major river systems in the world show that river cleaning is fraught with many institutional and technological problems. Some fully or partially successful river cleaning programmes such as those of cleaning the rivers Rhine, Danube, Thames, and the Ganges required

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institutions effecting international cooperation and the participation of local stakeholders.

Literature shows the following guiding principles for a successful river cleaning programme (see Imhoff et al. 1991 for discussion).

(i)Preventing pollutants from entering the water system is always preferable to treatment after entry.

(ii) A full account of relative share of sources, pollutants, and effects should precede treatment. It helps because there are scale economies in most waste treatment processes.

(iii) The retention of pollutants does not mean elimination. For example, removal pollutants heavy metals through absorption to sediments is not the permanent solution.

(iv) dilution is no solution of pollution abatement.

(v) The focus should not be on only one environment media. It could result in the transfer of pollution from one media to other as is the case with incineration of solid waste which transfers pollution from water and land to air.

(vi) Coordinated multi-point treatment strategies are preferable to single point treatment strategies for preventing huge damages from accidents.

(vii) Strict regular monitoring coupled with external regulation is needed to achieve the highest level of efficiency of waste treatment system.

(viii) The benefits of clean river as well as the cost of cleaning are defused. The economic instruments of polluter pay policy and pollution taxes have to be used to ensure that benefits of cleaning exceeds the costs.

(ix) The pollution standards as part of environmental regulation should be technologically and economically feasible and realistic.

(x) River cleaning is very expensive and the cooperation of all stakeholders is required for sharing its cost. We discuss in this chapter to what extent the design and implementation of the GAP in India is guided by these principals.

GANGA ACTION PLAN: AN AMBITIOUS RIVER CLEANING PROGRAMME IN INDIA

The Ganges is one of the most important river systems in the world. This 2510 long river has a basin covering 861,404 square km. Currently, half a billion people, almost one-tenth of the world's population, live within the river basin, at an average density of over 500 square km, and this population is projected to increase to over one billion people by the year 2030. There are about 52 cities, 48 towns, and thousands of villages in its basin. Nearly all the sewerage from these populations goes directly into the river, totalling over 1.3 billion litres per day, along with a further 260 million litres of industrial waste, run-off from 6 million tonnes of fertilizers and 9000 tonnes of pesticides used in agriculture within the basin, and large quantities of solid waste, including thousands of animal carcasses and several hundred human corpses released into the river every day for spiritual rebirth. The inevitable result of this onslaught onto the river's capacity to receive and assimilate waste has been an erosion of river water quality, to the extent that, by the 1970s, large stretches (over 600 km) of the river were effectively dead from an ecological point of view.

The GAP, an important environmental project to clean the Ganges, originated from the personal intervention and interest of the late Indira Gandhi. The GAP was launched in February 1985 and the late Prime Minister, Rajiv Gandhi stated, 'The Ganga is a symbol of our spirituality, our tradition, our tolerance, and our synthesis. But it is the most polluted river with sewerage and pollution from cities and industries thrown into it. From now, we shall put a stop to all this. We are launching this plan—not for the Public Works Department, but for the people of India'. The final cost of the GAP has been estimated at Rs 700 crore or 7 billion for phase I and Rs 420 crore or 4.2 billion for phase II. The operating costs of the programme run at around Rs 356 million.[1] The GAP has been perhaps the largest single attempt to clean up a polluted river anywhere in the world. Although a number of other international scale river basin clean-up programmes have been effectively implemented in other countries, none has the full spectrum of geographical, ecological, and socio-cultural complexities which faced the Indian Government during implementation of the GAP. The sums of money referred to above are large by any standards, and were committed with the main objective of raising the river water quality to bathing standard. As a result of GAP, the quality of water in the Ganges has shown varying improvements in absolute terms since 1985. The dissolved oxygen levels have been improving in the areas of Kanpur, Allahabad, and Varanasi after 1992. In the lower stretch, at Nawabganj, however, dissolved oxygen levels have continued to decline. Similar improvements in phosphate and nitrate concentrations have been observed since the early 1990s.

The assessment of river quality changes as a result of the GAP could be correctly made by comparing the conditions of the river in the late 1990s (without the GAP) with those with the GAP. Such a comparison has to be carried out using a sophisticated water quality model. The results of such a model in the case of Ganges show that some improvements in water quality (measured in terms of dissolved oxygen and BOD were observed everywhere, albeit they were quite small in some places. It is also worth noting that a total stretch of about 437 km still violates the permissible level of 3.0 mg/l of BOD. In terms of dissolved oxygen the level throughout the river is now more than 5.0 mg/l. Without the GAP, more than 740 km would have violated the BOD limit, with about 1000 km violating having BOD levels in excess of 10 mg/l. So, in summary, some improvements in water quality have been achieved. The important question is, what are these worth in money terms, taking account of the broadest set of values placed on cleaner water? It is this question that is addressed in this chapter.

The GAP is a good example of how environmental federalism works. Cooperation among the riparian countries or provinces in a federal country is a pre-requirement for any river cleaning programme. A polluted river causes more damages to countries downstream and benefits from river cleaning upstream accrue to the countries downstream. Therefore, a contract among the riparian states agreeing on the principles to share the cost of cleaning is an essential first step for any river cleaning programme. A programme to clean the Ganges, a river flowing through three provinces (Uttar Pradesh, Bihar, and West Bengal) of the Indian federation requires cooperation between the Centre and provinces and among different provinces in India. In fact, all the three levels of government (Central, provincial, and local) in the Indian federation are involved in the construction and maintenance of GAP programmes.

According to the polluter pay principle, the cost of cleaning Ganges has to be borne mainly by households and industries—the main polluters, in its basin. The entire capital cost of the project is met by the Central Government while the operation and maintenance (O&M) cost is shared by Central and provincial governments. The various schemes for cleaning Ganges comprise projects for interception and diversion of sewage, sewage treatment plants (STPs), low cost sanitation projects, and river-front development projects. In the current cost sharing arrangement, the households, the main polluters of Ganges are paying for cleaning Ganges to the extent of paying sewerage charges to local governments. These payments may meet only a small part of O&M cost of STPs. As per the current environmental regulation in India, all the water polluting industries have to meet the effluent standards fixed by the Central and state pollution control boards. Therefore, industries located in the Gangetic basin and polluting the Ganges have to incur the cost of meeting the prescribed standards. This cost incurred by the industries becomes part of the cost of cleaning Ganges in India. Almost the entire cost of treating household-borne effluents has to be met by the government out of the general taxes that it collects from the public.

BENEFITS AND BENEFICIARIES FROM CLEANING GANGES

There are multiple benefits from cleaning the Ganges.[2] Table 5.1 describes the benefits and beneficiaries from the river cleaning. There are benefits accruing to people who stay near the river or visit the river for pilgrimages or tourism. These will be in the form of recreation and health benefits and are called user benefits. The other category of benefits are those accruing to the people who are not staying near the river but enjoy benefits by knowing the river is clean. This category of people can be both Indians and foreigners. These are called non-user benefits arising out of people's preferences for the bio-diversity or the aquatic life that the Ganges supports and the religious significance of the river. The fishermen get benefits of improved fish production. It is found that farmers get some type of irrigation and fertilizer benefits, by using treated water and sludge from the STPs of GAP. The investment projects for cleaning Ganges provide employment to unemployed or underemployed unskilled labour in India. Also, cleaning the Ganges contributes benefits in the form of cost savings to water supply undertakings along the river. The beneficiaries from cleaning the Ganges can now be classified as users, non-users, health beneficiaries, farmers, unskilled labour, and fishermen.

Table 5.1: Identification of Benefits and Beneficiaries from Cleaning the Ganges

Benefits Class	Benefit Category	Beneficiaries
User	In stream withdrawal	Recreation users, farmers, fishermen, industries and households (agriculture, industrial, and commercial)
	Aesthetic, ecosystem	Recreation users, general ecosystem support (food chain)
Non-user	Vicarious Consumption and stewardship (existence and bequest values)	Indian public and international communities

Source: Markandya and Murty (2000).

The non-user benefits of Ganges arise out of motives people have to bequeath the bio-diversity the river supports to the future generation (bequest motive), for getting reassured about the conservation of Ganges with the knowledge that the river is kept clean and the aquatic life is protected (existence motive), and to protect the people living in the river basin from water-borne deceases (altruistic motive).

The Ganges supports 25000 or more of species of bio-diversity ranging from micro-organisms to mammals. There are a number of international species comprising mammals, reptiles, and birds supported by the Ganges ecosystem. The Ganges dolphin, irrawady dolphin, finless porpoise, and a variety of otters are some of the important mammals found in the Ganges. In the case of bird life, osprey, ring tailed fishing eagle, and Indian skimmer are important species. A variety of crocodiles including gharial, marsh crocodile or Maggar, and salt-water crocodile, and a number of turtles unique to the Ganges are the reptiles supported by the Ganges. The GAP has helped in preserving these species in four ways. First, there are some species for which there have been in situ conservation and captive breeding programmes. Second, the GAP has raised awareness and encouraged conservation efforts through information dissemination. Third, the GAP has facilitated the collection of information on species and their habitat, something that will contribute in an important way to their conservation. Finally, the general improvement of the quality of water of Ganges has helped most of the above species.

The international significance of many species mentioned above can result in placing substantial non-use values on the Ganges by the international communities. Therefore, international communities can potentially contribute money for cleaning the Ganges if India desires such support. The resource constraints and the very high opportunity cost in terms of foregone development benefits from the conservation programmes of Ganges may make this option attractive to India for river cleaning programs in future.

ESTIMATION OF BENEFITS AND COSTS OF GAP

User and Non-user Benefits

The user and non-user benefits of cleaning the Ganges are estimated using the CV methods of survey of households (see Freeman 1993 and Mitchell and Carson 1993 for the detailed description of contingent valuation methods). These benefits are described as people's willingness to pay for cleaning the river. The survey to estimate non-user benefits is aimed at the urban literate population in India while the survey of user benefits is aimed at people living nearer to the river and the visitors to the river. The survey for measuring non-user benefits was conducted among the households in 10 major cities in India, with the sample consisting of 250 households from each city. Each household was asked to place value on the three scenarios of river quality: (i) quality before the river clean-up, (ii) the current quality, and (iii) bathing quality. The WTP function relating these values to socio-economic characteristics of households and the river quality was estimated. Similarly, for measuring user benefits, a sample of users of Ganges from the residents, tourists, and pilgrims in the major cities along the river were surveyed.

The following independent variables are considered in the estimation of WTP functions for non-users and users.

ILOG (or LogINCOME) = Log (per capita annual household income from all sources)

ALOG (or LogAGE)	=	Log (Age of the respondent)
SLOG (or LogSIZE)	=	Log (Size of the household: with members below the age of 18 converted to adult equivalent units)
ELOG (or LogEDU)	=	Log (Education level of the respondent, in years)

INF_CL	Dummy variable: Whether or not respondents had heard about the Ganga Action Plan; YES = 1; NO = 0
VISIT	Dummy variable: Whether respondents had visited the Ganga in the past 10 years: YES = 1; NO = 0
B_STAND	Dummy variable: Whether respondents felt bringing water quality up to bathing standards was worthwhile, irrespective of cost; YES = 1; NO = 0
D_STAND	Dummy variable: Whether respondents felt bringing water quality up to drinking standards was worthwhile, irrespective of cost; YES = 1; NO = 0
MADRAS	Dummy variables: Whether the respondent resided in that particular city:
DELHI, etc.	Yes = 1; No = 0.

The variable QUALITY, an index of river water quality was calculated using the statistics on BOD measured at different points along the Ganges in the years 1987 and 1996. The data on BOD levels from 14 monitoring stations along the Ganges during the years 1985 and 1996 were used to construct the river quality index. The BOD level in the river in a given year is calculated as the weighted average of BOD levels at 14 monitoring stations in that year. Taking the bathing quality of the river as the best quality having an index of 100, the indices for the current quality (quality in the year 1996) and the past quality (quality in the year 1985) are calibrated. The values taken by the Quality Index in the three scenarios are:

Best Quality = 100.00
1995 Quality = 48.63
1985 Quality = 31.46

Simulations based on the mathematical modeling of the Ganges river water quality done by the National River Conservation Directorate, Ministry of Environment and Forests, Government of India show that the current quality (quality in the year 1996) of river without the GAP could have been worse than the quality of the river before 1985, the year of starting of GAP. The model predicted 5 per cent less dissolved oxygen in the year 1996 without GAP.

The dependent variable in the WTP function is household WTP. The survey provides data on three bids of households corresponding to three indices of river quality described above. Thus each household in the sample provides three observations on its WTP. The data collected from the households for the three scenarios of river quality are pooled so that the number of observations on each variable are three times the number in the original sample of households for each scenario. Given the values of other variables for any observation, the dependent variable or bid variable takes different values for the different indices of river quality.

In the regression equations described in Tables 5.2 and 5.3, almost all the variables are statistically significant (indicated by the high t-ratios). Along with the fact that the adjusted R^2 is high (as well as the F-ratio, which represents the overall significance of the regression), these high t-ratios make the interpretation of the results more meaningful. Also, all the variables have the expected sign: income is expected to be positively related to WTP, as are size of the household and the educational level. The educational level may also be interpreted as a proxy for the environmental awareness of the respondent.

Replacing all the RHS variables by their mean values and setting the QUALITY index equal to 100 gives the estimated mean WTP for Best or Bathing Quality, while setting the QUALITY index equal to 48.63 gives the estimated mean WTP for Current (1995) Quality, and setting it to 31.64 gives the estimated mean WTP for Past (1985) Quality. Table 5.4 provides the estimates of WTP per household for non-users and users for each of these water quality levels. The extrapolation of household WTP for user and non-user benefits to the beneficiary population requires the information about the size of the population given the estimates of household mean WTP. The beneficiary population for non-user benefits constitutes the urban

Table 5.2: Parameter Estimates of Willingness to Pay Function for Non-Users

Variable	Coefficient	t-statistic
CONSTANT	–3.932 ***	–5.087
QLOG	1.474 ***	26.779
ILOG	0.286 ***	6.172
ALOG	–0.374 ***	–4.247
SLOG	0.237 ***	2.995
ELOG	0.353 *	1.611
VISIT	0.227 ***	3.355
INF_CL	0.293 ***	3.833
B_STAND	0.177	1.611
D_STAND	0.126 **	2.354
MADRAS	0.785 ***	6.789
DELHI	–0.174 **	–1.919
TVM	0.099	0.840
BLE	0.208 **	2.015
BARODA	0.219 **	2.040
KLA	–0.541 ***	–6.776
HYV	0.254 **	2.024

Dependent variable:	LBID	Number of observations:	2237
R-squared	0.334	Adjusted R-square	0.330
F-statistic (zero slopes)	69.6797		

Standard Errors are heteroskedastic-consistent (HCTYPE=2).

Notes: *** denotes significance at the 1 per cent error level; ** denotes significance at the 5 per cent error level; * denotes significance at the 10 per cent error level.

Source: Markandya and Murty 2000.

literate population in India. An estimate of urban literate population of households in 23 cities having population one million and above in India is given as 8.733 million (Markandya and Murty 2000). The beneficiary population of user benefits is assumed to constitute the urban literate households located within 0.5 km of the river. The population of user households is estimated as 37,213 (Markandya and Murty 2000). Table 5.5 provides the estimates of annual aggregate incremental user and non-user benefits from GAP. If the pilgrims to various ghats of the river are also considered as users of Ganges, the user benefits could be very high—running into several thousands of millions.[3]

Table 5.3: Parameter Estimates of Willingness to Pay Function for Users

Variable	Coefficient	t-statistic
CONSTANT	-8.667 ***	-10.174
QLOG	1.651 ***	25.693
ILOG	0.258 ***	5.218
ALOG	0.220 **	1.844
SLOG	0.379 ***	5.199
ELOG	1.315 ***	5.447
VISIT	-0.116	-1.292
B_STAND	-0.057	-0.533
D_STAND	0.208 ***	3.197
CITY1	-0.043	-0.371
CITY2	-0.277 ***	-3.595
CITY3	0.043	0.410

Dependent variable:	LBID	Number of observations: 1658	
R-squared	0.333	Adjusted R-square	0.339
F-statistic (zero slopes)	74.7823		

Standard Errors are heteroskedastic-consistent (HCTYPE=2).

Notes: *** denotes significance at the 1 per cent error level; ** denotes significance at the 5 per cent error level; *denotes significance at the 10 per cent error level.

Source: Markandya and Murty 2000.

Table 5.4: Mean Willingness to Pay for Non-users and Users

(*Rupees per thousehold per annum at 1995–6 prices*)

Levels of Water quality	Bathing quality	1995 quality with GAP	1985 quality with gap	1995 quality without GAP
Non-users	557.94	192.81	101.48	97.51
Users	581.59	167.23	93.28	71.12

Source: Markandya and Murty (2000).

Health Benefits

Health benefits are estimated by using the survey data of population affected from Ganges pollution. The health benefits are estimated by a study conducted by the All India Institute of Hygiene and Public Health (AIIH & PH), Calcutta. Data were collected about the health of a sample of population living along the Ganges in the two

Table 5.5: Aggregate Willingness to Pay for Changes in Ganges Water Quality

(*Rs million at 1995–6 prices*)

Change in water Quality level	Non-user Benefits	User Benefits
1985 to bathing quality	4021.1	32
1985 to 1995 quality	797.7	5
Simulated to bathing quality	3986.5	33
Simulated to actual 1995 quality	832.3	6

Source: Markandya and Murty (2000).

scenarios: with and without river cleaning. Since cross-section data are used in estimating the health benefits, the data on the health of the population in the control region are used for the scenario without river cleaning. The health benefits are estimated as the improvement in user income due to reduction in working days lost due to illness from water-borne diseases.

Both recreational and health benefits are regarded as user benefits. The recreational benefits to the literate households living along the Ganges are estimated using the CV method as described already. The health benefits are estimated as increased income due to the reduced number of working days lost from illness to the river users belonging to lower income groups. However, there is a possibility that the WTP responses of literate households in the CV survey may capture the health benefits to them along with recreational benefits.

The study conducted by the AIIH&PH (1997) presents 'before' and 'after' the GAP data on the health population living along the Ganges river. The benefits from improved water quality from the GAP are estimated based: (i) increases in the users income due to reductions in working days lost, (ii) savings in the cost of treatment of raw water drawn from the river for public supply due to the GAP. A health survey was conducted in selected areas affected by Ganges pollution in six towns on the Ganges and corresponding studies were conducted among a group of control areas in the same towns, except that they have not been affected by the GAP. These towns are Hardwar, Kanpur, Chandannagar, Titagarh, Patna, and Nabadwip.

Morbidity and mortality data were collected respectively for six month and twelve month periods. Using the data from the survey, the yearly benefits of improvements in water quality of the river due to GAP were estimated in terms of increase in household incomes for each of the six study areas (where average number in household is assumed to be five). This is based on the difference between the number of working days lost due to sickness for the pre-project site or the control area and the number lost in post-project study areas. These figures for decreases in the number of household days lost are multiplied by the average daily income of households in each study area. The results are given in Table 5.6.[4] The total number of users in the six study areas is 473,550 and the total benefits estimated are Rs 34.84 million. Hence the average annual benefit of improvements to water quality based on reductions in working days lost through sickness is calculated as Rs 73.57 million per million users.

Table 5.6: Health Benefits from Reduced Loss of Working Days

Town	Average no. of working days saved yearly (family)	Regular users of Ganga in town (no. of families)	Individual daily income (Rs)	Total value (Rs million)
Haridwar	6.09	41,300	64	16.00
Kanpur	3.42	15,560	35	1.86
Patna	6.58	22,480	88	12.94
Chandannagar	6.44	5,690	38	1.37
Nabadwip	7.37	4,760	65	2.28
Titagarh	2.61	4,920	31	0.39

Source: AIIH&PH (1997).

The sewage from towns and cities along the Ganges is used for irrigation by small farmers. There could be health benefits to sewage farm workers from the GAP projects. A study by AIIH&PH of health conditions of sewage farm workers of Titagarh town before and after water quality improvement schemes indicated that worm and protozoal infestation was reduced in workers in the post-project period. These results were used as a basis for a notional estimate of a reduction of four days per month in working days lost per sewage farm worker due to these improvements. Therefore, the total monetary benefit was calculated as Rs 480,000 per year 100 per sewage farm workers.

In order to estimate the total annual health benefits for GAP, the loss of working days in the Ganges River area is calculated as follows.

Gain in value of working days due to GAP per user: Rs 73.57	
Area within 0.5 km of river:	252 square Km.
Average density:	500 per square Km.
Hence total population affected:	1,262,500
Hence total value of gain in working days	Rs 92.88 mn

Thus the annual gain in health benefits by avoiding the loss of working days is estimated as Rs 92.88 million. The other category of health benefits considered in this chapter are for sewerage farm workers. These benefits work out to Rs 4800 per worker per year. Assuming that there are 100 workers for each of the 35 GAP sewage treatment schemes, this would amount to a total benefit of Rs 16.8 million.

Benefits to Water Supply Undertakings

The AIIH&PH study also looked at the likely costs of the treatment of water for public supply had water quality not been improved by the implementation of GAP. It is likely that without the GAP, the present system of water treatment followed (after the GAP) would be inadequate to provide water quality for drinking purposes. Reaching this standard would require the upgrading of treatment technology by at least introducing activated carbon absorption techniques for the removal of toxic chemicals and heavy metals. The additional cost of this technology was calculated for the six towns in the study based on the assumption of the cost of activated carbon absorption techniques of Rs 3000/- per million litres. The results are given in Table 5.7 and show a total benefit per year from implementation of GAP of Rs 731.29 million for the six towns. This indicates that in Calcutta, where water supply from the Ganges is 900 million litres per day (MLD), the yearly benefit of improved water quality through GAP is Rs 985.5 million.

Although the above estimates are useful information, they cannot be included in the cost benefit analysis as such. The reason is that the study is measuring the improvements in health and other factors resulting from the improvements in water quality. If one then adds the costs of an alternative method of improvement as a benefit, one is double counting. If there had been no GAP, the health and other benefits would not have materialized. Of course if water treatment costs fall compared to what they were before GAP, those savings are correctly to be added to GAP benefits. But the above cost savings are relative to a technique that is an improvement in water treatment which achieves the goals of GAP.[5]

Table 5.7: Benefit of GAP Water Quality Improvements as Measured by Savings in Water Treatment Expenditure

Town	Population	Water Supply* (MLD)	Benefit per Year (Rs million)
Titagarh	114085	17.11	18.74
Chandannagar	120378	18.06	19.78
Napadwip	104533	15.68	17.17
Patna	1376701	206.51	226.13
Kanpur	2037333	305.6	334.63.
Haridwar	699230	104.88	144.84
Total			731.29

Source: Markandya and Murty (2000).

Agricultural Benefits

Benefits to farmers are estimated using the data from a survey of farmers who use using water from STPs of GAP. Benefits to farmers are estimated as value of incremental farm output due to irrigation and savings in the cost of conventional fertilizers from making use of the partly treated water from STPs. The GAP 35 STPs with a capacity to treat waste water volume of 919.82 MLD. For estimating irrigation benefits of GAP projects, a survey of 108 farmers around STPs in Kanpur and 116 farmers around STPs in Varanasi was conducted in August 1996. The survey collected information about the cropping pattern, crop productivities, input use, and the sources of irrigation for the farms around the STPs, and the socio-economic characteristics of farmers' households.

Given the volume of waste water treated by the STPs and an estimates of waste water capacity per day required to irrigate one hectare of land, the annual irrigation potential of STPs can be estimated. An estimate based on the data collected through the survey of farms shows that to irrigate 1000 hectares of land, a STP of 74.3 MLD capacity is needed. On the basis of this estimate, it is calculated that the 919.82 MLD waste water capacity of STPs of GAP can irrigate 12,380 hectares of land. The estimate of average annual yields per hectare of cropped area based on the survey data for GAP and non-GAP farms are respectively given as Rs 16,837 and Rs 9518. Therefore, the incremental benefits per hectare of irrigated land in GAP farms is estimated as Rs 7319. The annual incremental benefits from irrigating 12,380 hectares of land by the GAP projects can now be estimated as Rs 90.61 million at 1995–6 prices.[6]

Savings in conventional fertilizers for the GAP farmers could be obtained by comparing the estimates of conventional fertilizers used by the GAP farmers and non-GAP farmers. The estimated cost of conventional fertilizers per hectare of GAP and non-GAP farms based on the survey data are respectively given as Rs 150 and Rs 687. Therefore, the per hectare incremental benefits for savings in fertilizer cost due to GAP projects is estimated as Rs 535. The annual incremental benefits from the savings in the fertilizer cost can now be estimated as Rs 6.6 million at 1995–6 prices.

The sludge generated in the process of treating waste water by STPs has been found to have fertilizer potential. The data for waste water volume in terms of MLD and the annual quantity of sludge generated for STPs at Mirzapur and Kankhal at Haridwar shows that for a waste water volume of one MLD, about 8.036 MT of sludge can be generated annually. Given the total waste water volume of 919.82 MLD from all STPs of GAP, the total amount of sludge generated annually by the GAP projects can be estimated as 73914.30 MT. NEERI (1995) provides the chemical analysis of sludge from some STPs from the Varanasi and Kanpur areas. According to the NEERI analysis, the average concentration of fertilizers in the sludge are estimated as 18.37 Kg/MT, 5.08 Kg/MT and 4.68 kg/MT respectively for Nitrogen, Phosphorous, and Potassium (Table 5.6). Given these estimates, annual fertilizer potential of sludge from GAP projects can be estimated as 1357.805 MT of Nitrogen, 375.485 MT of Phosphorous, and 345.919 MT of Potassium.

The retail prices of fertilizers, Nitrogen, Dai, and Phosphatic (DAP) and Potash are respectively given as Rs 4000, Rs 12000 and Rs 6000 per MT during the year 1995–6 in the surveyed areas. Given these prices, the value of fertilizers in the total sludge are estimated as Rs 5.43 million for Nitrogen, Rs 4.51 million for Phosphorous and Rs 2.08 million for Potash. Therefore, the total value of fertilizers in the sludge annually generated by the GAP projects is estimated as Rs 12.02 million at 1995–6 prices.

Fisheries Benefits

GAP can contribute to the increased supply of fish and reduce the risk of fish infection or contamination. For estimating the benefits from improved fish supply from the Ganges, the data are needed about fish species caught and catch volume, catch effort, fish prices, and the significant non-GAP changes and GAP changes that could affect fish catch. Unfortunately, the reliable data on these various items are not available so that the fisheries benefits from the GAP could not be estimated. Given that the incremental fisheries benefits accrue mainly to fishermen in the Gangetic basin belonging to a very low income group in the Indian economy, these benefits assume importance from the point of view of income distributional effects of GAP in the estimation of social benefits.

Benefits to Unskilled Labour

There are employment benefits to unskilled labourers due to GAP. Empirical studies on employment in the Indian economy show that there is surplus unskilled labour, especially in the rural or agricultural sector. The construction and O&M of GAP projects create employment for these unemployed labourers and contribute to an increase in their real incomes. Out of the total investment of Rs 7657.37 at 1995–6 prices made on the GAP projects during its first phase, Rs 1837.77 million were paid as wage bill to unskilled labour. Out of annual expenditure of Rs 355.703 million on the O&M cost of GAP projects, Rs 81.645 million were paid as the wage bill to unskilled labour.

There is empirical evidence to show that the shadow wage rate or the incomes foregone by the unskilled labourers by switching from employment in agriculture to the industrial projects is negligible. Also with the presence of underemployment or disguised unemployment in agriculture, the cost to the Indian economy (loss in national income) by shifting unskilled labourers from farm employment to industrial employment could be zero. Therefore, there are social benefits from the employment of unskilled labourers on the GAP projects first due to increased income due to employment and second due to the redistribution of income to unskilled labourers belonging to the low income group in the Indian economy.

Costs of Cleaning Ganges

Costs to Government

The total funds released by the Government of India for the investment expenditure of GAP (under both GAP phases, I and II) at 1995–6 prices were Rs 7657.37 million during the period 1985–6 to 1996–7. Of the total funds released, Rs 7045.40 million was for GAP Phase I and the remaining Rs 611.97 million for GAP Phase II. However, the total actual investment under GAP Phase I is Rs 6397.25 million. This includes Rs 2769.88 million in Uttar Pradesh, Rs 2782.94 million in West Bengal, and Rs 844.43 million in Bihar. Table 5.8 also provides information about the time phasing of investment expenditures for GAP Phase I during the period 1985–6 to 1996–7. These expenditures cover a large number of water pollution abatement projects contributing to the clean up of the Ganges. They have also created employment for a large number of surplus unskilled labourers in the states of Uttar Pradesh, Bihar, and West Bengal in the Gangetic basin.

Estimates based on the detailed data on the construction of three STPs show that the expenditures on skilled and unskilled labour constitute respectively 22 per cent and 24 per cent of the total capital cost of GAP projects. That is, out of the total capital cost of Rs 7657.37 million at 1995–6 prices, the unskilled labour and skilled labour employed for the construction of GAP projects amount to Rs 1837.77 million, and Rs 1684.62 million respectively. Table 5.8 provides details of the composition of the capital cost of GAP in terms of domestic material, and skilled and unskilled labour.

Expenditure on the O&M of projects under GAP Phase I during the period 1986–7 to 1996–7 at 1995–6 prices was Rs 355.70 million. This breaks down to Rs 231.36 million (66 per cent) for Uttar Pradesh, Rs 67.87 million (19 per cent) for West Bengal, and Rs 56.48 million (15 per cent) for Bihar. Data on the O&M expenditure of GAP II are not available and, therefore, the estimates of these expenditures are obtained by assuming that the ratio of O&M cost and capital cost of GAP II is same as that of GAP I. An estimate of O&M cost of GAP projects created so far under phase I and II is given as Rs 480.264 million.

Table 5.8: Domestic Material, Skilled Labour, and Unskilled Labour Components of the Capital Cost of GAP

(*Rs Million at 1995–6 Prices*)

Year	Domestic material	Skilled labour	Unskilled labour	Total Capital Cost
1985–6	83.09	33.85	36.93	153.87
1986–7	310.68	126.58	138.08	575.34
1987–8	478.33	194.88	212.59	885.80
1988–9	589.84	240.30	262.15	1092.29
1989–90	579.96	236.28	257.76	1074.00
1990–1	452.62	184.40	201.17	838.19
1991–2	381.94	155.61	169.75	707.30
1992–3	374.01	152.37	166.22	692.60
1993–4	416.47	169.67	185.10	771.24
1994–5	181.26	73.85	80.56	335.66
1995–6	144.30	58.79	64.13	267.21
1996–7	142.49	58.05	63.33	263.87
Total	4134.99	1684.63	1837.77	7657.37

Source: Markandya and Murty (2000).

Estimates of share of skilled and unskilled labour in the total operating cost of GAP projects based on the detailed data of three STPs and three municipal pumping stations (MPSs) show that they form respectively 4 per cent and 17 per cent of O&M cost. Table 5.9 provides the time phasing of O&M expenditure of GAP, at 1995–6 prices. Out of the total O&M cost of Rs 480.26 million at 1995–6 prices, skilled and unskilled labour account for Rs 19.21 million, and Rs 81.65 million respectively as given in Table 5.9.

Table 5.9: Domestic Material, Skilled Labour, and Unskilled Labour Components of O&M Cost of GAP

(*Rs million at 1995–6 prices*)

Year	Domestic material	Skilled labour	Unskilled labour	Total O&M Cost
1986–7	5.088	0.258	1.095	6.440
1987–8	10.391	0.526	2.236	13.153
1988–9	22.021	1.115	4.739	27.875
1989–90	29.693	1.503	6.390	37.586
1990–1	20.008	1.013	4.306	25.327
1991–92	38.297	1.939	8.241	48.477
1992–93	38.288	1.939	8.239	48.465
1993–94	46.865	2.373	10.085	59.322
1994–95	42.272	2.140	9.097	53.509
1995–96	82.580	4.181	17.770	104.532
1996–97	43.906	2.223	9.448	55.577
Total	379.409	19.211	81.645	480.264

Source: Markandya and Murty (2000).

Cost to Industry

The international experience of river cleaning programmes including that of the Ganges in India shows that a combination of instruments and institutions have to be used to achieve the river cleaning objectives. Environmental regulations requires the polluters to comply with safe environmental standards. The compliance to the environmental standards requires both private and public investments. In the case of cleaning the Ganges, there is public investment through the project GAP and there is private investment by industries in the Gangetic basin. It is mandatory for the industries to invest in pollution control to meet the national standards for water quality. There are 68 heavily polluting industries in the Gangetic basin generating 2.6 million kilolitres of effluent every day. The data about the pollution abatement cost collected for a sample of 18 water-polluting industries in the river basin that are meeting the effluent standards provides an estimate of Rs 0.39 per kilolitre of water treated at 1993–4 prices (Murty et al. 1992). The daily cost of treating 2.6 million kilolitres of effluent is Rs 1.014 million. The annual cost of effluent treatment for the water polluting industries in the river basin is estimated at Rs 370.11 million.

ESTIMATES OF SOCIAL BENEFITS OF GAP

Estimates of time flows of benefits and costs at market prices described in the earlier section can be used to estimate the social benefits of cleaning the Ganges. For estimating the social benefits of GAP using the methods of social cost–benefit analysis of investment projects (Dasgupta, Marglin, and Sen 1972; Little and Mirrlees 1974), one requires estimates of social rate of discount and shadow prices of investment and unskilled labour for the Indian economy. The social cost of investment in GAP could be greater than the cost at market prices or the financial cost because of scarcity of capital. The social cost of employing unskilled labour on the project could be lower than the wage bill paid at market wage because there is surplus unskilled labour in the Indian economy. Similarly, the social rate of discount is lower than the market rate of interest because of the presence of economic externalities in the accumulation of capital; the society will have lower time preference rate for savings than the rate individuals have in the free market. Murty et al. (1992) provide estimates of social rate of discount and shadow prices of capital and unskilled labour for the Indian economy. These estimates are in the 10 to 12 per cent range for the social rate of discount, 40 per cent premium for capital (the shadow price of capital is 40 per cent higher than the market price), and 50 per cent of market wage as shadow wage rate.

The criteria of net present social value, internal rate of return, and the benefit–cost ratio can be used to estimate the social benefits of GAP. Considering the benefit and cost flows of GAP during the period 1985–2020, Table 5.10 provides estimates of present value of benefits and costs to various agents in the Indian economy from cleaning Ganges at 10 per cent rate of discount. The net present value of GAP at 10 per cent rate of discount is estimated as Rs 4147.51 million at shadow prices of investment and unskilled labour. The internal rate of return on investments on GAP is as high as 15.4 per cent. The benefit–cost ratio is estimated as.

Table 5.10: Estimates of Present Value of Benefits of Cleaning Ganges for Various Beneficiaries at Market Prices and with Income Distribution Effects

(*Rs million at 1995–6 prices*)

Beneficiaries	At shadow prices	With income distribution effects	
		ε =1.75	ε =2.0
Users	29.11	2.79	1.98
Non-users	6871.03	439.74	295.45
Farmers	574.93	1709.84	1997.88
Health beneficiaries	826.93	2549.29	2873.58
Fishermen	NA	NA	NA
Unskilled labour	1919.42	5708.36	6670.00
Industrial units	-1504.59	-144.44	-102.31
Government	-4569.32	-4569.32	-4569.32
Net present value	4147.51	5696.26	7167.26

Source: Markandya and Murty. 2000.
Note: Rate of discount is taken as 10 per cent. The cost to the government is the present value of the cost incurred up to the year 1996–7.

A pollution–free Ganges provides benefits to both rich and poor people. It is a source of livelihood to fishermen and farmers, and is useful to the people using it for drinking and bathing. Unskilled labour gets employment benefits from the GAP projects. The non-user benefits and the benefits from recreational and amenity services accrue mostly to rich people. From the equity point of view, the benefits from river cleaning accruing to poor people assume importance and contribute to the increased social benefits. If the estimates of income distributional weights to benefits accruing to various classes of beneficiaries from the Ganges are available, the social benefits of cleaning the Ganges from the equity point of view can be estimated. Suppose the social welfare function for the Indian economy is of the following form (Atkinson 1970).

$$W = \sum_{i=1}^{N} \frac{AY_i^{1-\varepsilon}}{1-\varepsilon} \tag{5.1}$$

where

W: Social welfare function

Y_i : Income of individual I

ε : Elasticity of social marginal utility

A: a constant

The social marginal utility of income is defined as:

$$\frac{\delta W}{\delta Y_i} = A y_i^{-\varepsilon} \tag{5.2}$$

Taking per capita national income, y as the numeraire, and giving it the value of one, (2.5) can be written from (5.2)

$$\frac{\delta W}{\delta Y_i} = A y^{-\varepsilon} \equiv 1 \tag{5.3}$$

Substituting $y^{-\varepsilon}$ for A in (5.1), the social marginal utility of income to the individual *i* (SMU_i) can be written as

$$SMU_i = \frac{\delta W}{\delta Y_i} = \left[\frac{y}{Y_i}\right]^{-\varepsilon} \tag{5.4}$$

The value of is in fact the weight to be attached to the costs and benefits to group i relative to costs and benefits to the person with income equal to the national percapita income. In order to compute these weights, data about y, Y_i, and ε are needed. Some recent studies in India on the estimates of ε have suggested a range of 1.75–2.0 for its value (Murty et al. 1992). *The Economic Survey*, *1995–6,* Government of India suggests an estimate of per capita GDP for the Indian economy of Rs 9321 at 1995–6 prices. The estimates of social marginal utility for various beneficiaries from cleaning the Ganges are given in Table 5.11.

The estimate of net present social value of GAP increases from Rs 4147.51 million to Rs 5696.26 million if income distributional benefits are accounted for.

SUSTAINABILITY OF PROCESSES OF CLEANING THE GANGES

A number of different mechanisms can be considered to raise resources to sustain the cleaning of the Ganges. They are a 'polluter pays'

Table 5.11: Estimates of Income Distributional Weights for the Incomes of Beneficiaries from Cleaning Ganges

Beneficiary group	Annual per capita income (Rs)	Income distributional weights	
		ε = 1.75	ε = 2.00
Unskilled labour, farmers, and health beneficiaries	5000	2.974	3.475
Urban users	35,000	0.096	0.068
Non-users	44,705	0.064	0.043
Industrial owners	44,705	0.064	0.043
Government	9321 *	1.000	1.000

Notes: Per capita incomes of urban users and non-users are estimated from the survey data. The per capita income of industry owners is assumed to be same as that of non-users; * National per capita GDP in 1994–5.
Source: Markandya and Murty (2000).

principle, a 'user pays' principle (with government involvement), a user pays principle (without government involvement), and funding from the general tax system.

The polluter pays principle would mean a water charge per kilolitre collected as a tax, or more likely as part of the water tariff, from households and industries. Given the general interest in employing market-based instruments to deal with water pollution, this would make a good case study and would assist in the design of a suitable tax system. A particular problem to be resolved would be to ensure that the tax is collected efficiently and passed on to the authority with the responsibility for cleaning the Ganges.

The user pays principle with government involvement places a tax on both user and non-user beneficiaries. An alternative to the involvement of the government is setting up a charitable commission for the Ganges with the responsibility to collect payments from user and non-user beneficiaries. The commission would have autonomy from the government but would be accountable to the public through the Commission for Charities or a similar body. It would have regional offices, which would not only collect money but would also be responsible for disseminating information about the Ganges and changes in its water quality.

Finally there is the possibility of using general taxes. This may not be a feasible instrument, given the extreme pressures on such tax revenues and the uncertainties created for future revenue flows to maintain the Ganges water quality. Of course there is no reason why only one of these options has to be implemented. It may, in fact, be possible to have a combination of an effluent tax and a voluntary payment scheme of the kind outlined here. The details have, of course, to be worked out, but the prospects of success seem good.

CONCLUSION

There are many institutional and technological challenges in river cleaning programmes. Many environmental and development issues will arise in river cleaning. They underscore the importance of cooperation of riparian states against non-cooperation to deal with cross-boundary pollution, the need for institutions and instruments to sustain the cleaning process, and the high values people place on river conservation with the accrual of benefits from the preservation of bio-diversity and aquatic life to both national and international communities.

The experience of river cleaning programmes including the programme to clean the Ganges suggests that a mix of instruments and institutions have to be used to achieve the objectives. They comprise direct public and private investments, economic instruments, and institutions facilitating local community participation.

There are multiple benefits from river cleaning programmes. As shown in this paper, the estimation of these benefits requires market and non-market valuation. Due to data problems, all the benefits from the GAP could not be estimated. With whatever benefits have been quantified, the GAP has significant positive net present social benefits at 10 per cent social rate of discount for the Indian economy. The internal rate of return is as high as 15 percent.

The environmentally sustainable agricultural and industrial development in India requires the continuation of processes of cleaning Ganges in future. Given that the international communities get benefits as non-users from cleaning Ganges, if required, Indian can get financial support from these communities to sustain the river cleaning.

NOTES

1. The average exchange rates in 1995 were Rs 54.5 to the pound sterling and Rs 35.2 to the US dollar. Hence the investment costs can be expressed as £ 205 million or $ 318 million. The operating costs are £6.4 million or $10million.
2. See Mitchell and Carson (1989), Figure 3.1, p.61 for a classification of benefits from an improvement of fresh water quality.
3. Markandya and Murty (2000) provide a rough estimate of annual user benefits (benefits to those living along the banks of the river and to pilgrims) as Rs 6680 million by improving the river quality to the bathing quality standard.
4. The data provided by AIIH&PH was for household incomes. Since the losses of days are for person days, the value of per person can be estimated by dividing the household income by the size of the household. It is assumed that individual incomes are half household incomes — that is there are two full-time earners per household.
5. An earlier reviewer of this study has noted that, for the seven cities along the Ganga the annual cost 'savings' are higher than the total benefits calculated in this study. This implies that, in a situation where water supplies have to come from the river, it is likely to be more cost effective to invest in water treatment plants to clean up polluted river water. There would be merit in examining this issue further.
6. An earlier reviewer of this work has questioned the valuation of the benefits in terms of gross value of returns rather than the net values after deduction of expenses. Taking the gross values is correct when the change in the environmental variable is small and when allowance is made for the fact that farmers can optimize with respect to crop mix, inputs etc. In that case it can be shown that the benefits of an improvement in an external factor such as water quality is the gross increase in yield.

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