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# Cost–benefit analysis of cleaning the Ganges: some emerging environment and development issues[1]

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ABSTRACT. This paper while attempting to estimate the social benefits of cleaning the Ganges river in India highlights some of the emerging environmental and development issues in the river cleaning programmes. Methods involving the market and non-market valuation of environmental goods are used to estimate the benefits. The benefits estimated include user and non-user benefits, health benefits to the poor households living along the river, and agricultural benefits to farmers among other benefits. However, the benefits from fisheries, one of the important components of benefits from the river cleaning, could not be quantified in this paper. With the benefits that could be quantified, the program of cleaning the Ganges has positive net present social benefits at a 10 per cent social rate of discount and an internal rate of return as high as 15 per cent. Furthermore the estimates of benefits of river cleaning obtained in this paper provide guidance for designing the policy instruments to raise revenue for sustaining the river cleaning processes in India. A number of different mechanisms are considered to raise the resources for sustaining the cleaning of Ganges. They are a polluter-pays principle, a user-pays principle (with government involvement), a user-pays principle (without government involvement), and funding from the general tax system.

## 1. Introduction

The Ganges is one of the most important river systems in the world. This 2,510 kilometre (km) 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 per 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

[1] This paper is mainly drawn from Markandya and Murty, 2000, Cleaning-Up the Ganges: The Cost Benefit Analysis of Ganga Action Plan, Oxford University Press, New Delhi. We are grateful to three anonymous referees of this journal and to Dr. Priya Shyamsundar for useful comments on an earlier draft.

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directly into the river, totalling over 1.3 billion litres per day, along with a further 260 million litres of industrial waste, runoff from the 6 million tons of fertilisers and 9,000 tons 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 on to 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 'Ganga Action Plan (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. The final investment cost of the GAP has been estimated at Rs. 7,657.37 million at 1995–1996 prices during 1985–1986 to 1996–1997. The operating costs of the programme are estimated as Rs. 480.264 million[2] during the same period. 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 comparison of the conditions of the river in the late 1990s without the GAP with the conditions 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 the Ganges show that some improvements in water quality (measured in terms of dissolved oxygen and biochemical oxygen demand (BOD)) were observed everywhere, albeit quite small ones 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 1,000 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 paper.

[2] 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 amount to £205 million or $318 million. The operating costs are £6.4 million or $10 million.

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The GAP is a good example of how environmental federalism works. Co-operation among the riparian countries or provinces in a federal country is a pre-requisite for any river cleaning program. A polluted river causes damages to countries down-stream and, as a consequence, benefits from river cleaning up-stream accrue to the countries down-stream. 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 program. A program to clean the Ganges, a river flowing through three provinces (Uttar Pradesh, Bihar, and West Bengal) of the Indian federation requires co-operation between the centre and provinces and among the provinces themselves. In fact, all the three levels of government (central, provincial, and local) are involved in the construction and maintenance of GAP programs.

According to the polluter pay principle, the cost of cleaning the Ganges should be mainly borne by households and industries, the main polluters, in its basin. The entire capital cost of the GAP, however, is met by the central government while the operation and maintenance costs are shared by central and provincial governments. The various schemes for cleaning the Ganges include projects for interception and diversion of sewage, sewage treatment plants, low cost sanitation projects, and river front development projects. In the current cost-sharing arrangement, the households, the main polluters of the Ganges, are paying for cleaning the Ganges to the extent that they pay sewerage charges to local governments. These payments meet only a small part of the operation and maintenance costs of sewage treatment plants. As per the current environmental regulations 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 cost of cleaning the Ganges in India. Almost the entire cost of treating household borne effluents has to be met by the government out of general taxes it collects from the public.

## 2. Benefits and beneficiaries from cleaning the Ganges

There are multiple benefits from cleaning the Ganges.[3] Table 1 describes the benefits and the beneficiaries of the river cleaning programme. 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 gain welfare from 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 the Ganges supports and the religious significance of the river. Other beneficiaries include fishermen, farmers, and those for whom employment

[3] See Mitchell and Carson (1989: figure 3.1, p. 61) for a classification of benefits from an improvement of fresh water quality.

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Table 1. *Identification of benefits and beneficiaries from cleaning the Ganges*

| *Benefits class* | *Benefit category* | *Beneficiaries* |
|---|---|---|
| User | Instream | Recreation users |
| | Withdrawal | Farmers, fishermen, industries and households (agriculture, industrial and commercial) |
| | Aesthetic | Recreation users |
| | Ecosystem | General ecosystem support (food chain) |
| Non-user | Vicarious consumption and stewardship (existence and bequest values) | Indian public and international communities |

is created as a result of the project. Fishermen get benefits of improved fish production. Farmers get some type of irrigation and fertiliser benefits by using treated water and sludge from the sewage treatment plants of the GAP. The investment projects for cleaning the 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. Hence the beneficiaries from cleaning the Ganges can be classified as users, non-users, health beneficiaries, farmers, unskilled labour, and fishermen. The non-user benefits of the Ganges arise out of motives people have to bequeath the bio-diversity the river supports to future generations (bequest motive); from being reassured about the conservation of the Ganges, with the knowledge that the river is kept clean and the aquatic life is protected (existence motive), and from the desire to protect the people living in the river basin from water borne deceases (altruistic motive).

The Ganges supports 25,000 or more of species of bio-diversity, ranging from micro-organisms to mammals. There are a number of international species comprised of mammals, reptiles, and birds supported by the Ganges ecosystem. The Ganges dolphin, irrawady dolphin, finless porpoise, and a variety of ottars are some of the important mammals found in the river. 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 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 etc. 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, general improvement of the quality of water of the Ganges has helped most of the above species.

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

## 3. Estimation of benefits and costs of GAP

### *3.1. User and non-user benefits*

The user and non-user benefits of cleaning the Ganges are estimated using the contingent valuation methods of survey of households.[4] These benefits are described as people's willingness to pay for cleaning the river. The Contingent Valuation (CV) survey instrument has three components: (i) scenario specification, (ii) elicitation, and (iii) socio-economic characteristics of the respondents. In the scenario specification, the information about the environmental good provided is given to the respondent. The environmental good provided in this case is the clean Ganges and the flow of environmental services from it. First an overview of the GAP including its year of inception and target (uniform bathing quality in the river) is given. Second, a brief summery is provided of basic causes of pollution in the river, pointing out that the domestic sewage from large cities is the single largest cause for pollution. Third, a brief account is made of activities of the GAP, ranging from the setting up of sewage treatment plants to constructing electric crematoria.

For value elicitation, respondents were shown a certain map of water quality of the Ganges (either of uniform bathing quality, or river water quality as it was in 1995 or in 1985) and were then asked to evaluate the benefits they perceived themselves. Three payment vehicles were considered: (i) payment to government, (ii) payment to a reputable charitable organization, and (iii) payment to a local citizen group (of which the respondent could become a member). The first option was rejected outright at the pre-testing stage, given the prevailing lack of confidence in government. The other two options were tried in pre-testing and found that the reputable charitable organization was the most acceptable payment vehicle. The elicitation format chosen is an open-ended bidding game. The respondents were asked two follow-up questions to their initial bid, one of which is a closed-ended question.

Socio-economic details of households for which information was collected are age, education and occupation of the respondent, the size of the household, and the gross annual household income from all sources. For measuring non-user benefits, the target population is restricted to the urban literate population in the major cities (population one million and above) in India. First, contingent valuation involves considerable hypothetical

[4] See Freeman III, 1993 and Mitchell and Carson, 1989 for a detailed description of contingent valuation methods.

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reasoning that would be difficult for illiterate respondents to follow. Second, willingness to pay for non-user benefits is constrained by income; if incomes are at subsistence levels, it will be difficult for respondents to reveal positive values. Cities were selected to achieve maximum geographical coverage. Within each city, the sampling scheme was designed to control for geographical spread and income categories. Accordingly, the city was divided into four geographical zones, and households in three income groups of high-income, middle-income, and low-income were sampled. The sampling in each geographical zone and income group was done by taking every alternate household along a street or in a complex of residential flats. There were 2,000 households surveyed in ten cities in India. For measuring user benefits, especially amenity benefits from the Ganges, the sample is limited to residents, tourists, and pilgrims (at bathing ghats). The sample is drawn from three cities, Allahabad, Varanasi, and Calcutta on the Ganges. Within each city, the sampling scheme is designed to cover residential areas within half a kilometre on either side of the river, and major pilgrimage centres, with control for geographical spread and income categories. Again for the residential sample, only literate households are chosen.

In the estimated bid or willingness to pay function, river quality, education level of the respondent, and family size are expected to have positive signs, while the age of the respondent is expected to have a negative sign. The dummy variables representing whether the respondent visited the Ganges previously, and whether he felt bringing water quality levels to either bathing quality or drinking quality are expected to have positive signs.

Each household was asked to place a value on the three scenarios of river quality: (a) quality before the river cleanup, (b) the current quality, and (c) bathing quality. The willingness to pay function relating these values to socio-economic characteristics of households and the river quality was then estimated.

The following independent variables are considered in the estimation of willingness to pay 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 ten years: YES = 1; NO = 0 |

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| | |
|---|---|
| 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 is calculated using the statistics on BOD (Biological Oxygen Demand) measured at different points along the Ganges in the years 1987 and 1995. 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 value 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 modelling 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 1995) of the river without the GAP could have been worse than the quality of the river before 1985, the year of starting of the GAP. The model predicted 5 per cent less dissolved oxygen in the year 1996 without the GAP.

The dependent variable in the willingness to pay function is household willingness to pay. 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 willingness to pay (WTP). The data collected about the households in the three scenarios of river quality are pooled so that the number of observations on each variable is 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 2 and 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

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Table 2. *Parameter estimates of willingness to pay function for non-users*

| Dependent variable: | LBID | | |
|---|---|---|---|
| R-squared | 0.334 | Number of observations: | 2237 |
| F-statistic (zero slopes) | 69.6797 | Adjusted R-squared | 0.330 |
| *Variable* | *Coefficient* | *t-statistic* | |
| CONSTANT | −3.931600*** | −5.08746 | |
| QLOG | 1.473850*** | 26.77850 | |
| ILOG | 0.285526*** | 6.17231 | |
| ALOG | −0.373782*** | −4.24718 | |
| SLOG | 0.236715*** | 2.99498 | |
| ELOG | 0.352119* | 1.61129 | |
| VISIT | 0.226198*** | 3.35536 | |
| INF_CL | 0.292159*** | 3.83297 | |
| B_STAND | 0.176796 | 1.61140 | |
| D_STAND | 0.125844** | 2.35420 | |
| MADRAS | 0.784868*** | 6.78864 | |
| DELHI | −0.173690** | −1.91892 | |
| TVM | 0.098726 | 0.84003 | |
| BLE | 0.207553** | 2.01479 | |
| BARODA | 0.218628** | 2.03979 | |
| KLA | −0.540680*** | −6.77557 | |
| HYV | 0.253662** | 2.02352 | |

*Notes*: Standard errors are heteroskedastic-consistent (HCTYPE = 2).
*** 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).

t-ratios make the interpretation of the results more meaningful. Also, all the variables have the expected sign. The educational level may also be interpreted as a proxy for the environmental awareness of the respondent.

Replacing all the right-hand side 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 4 provides the estimates of WTP per household for non-users and users for each of these water quality levels. The extrapolation of household willingness to pay for user and non-user benefits to the beneficiary population requires information about the size of the population given the estimates of household mean willingness to pay.

The beneficiary population for the non-user benefits constitutes the urban literate population in India. An estimate of the urban literate population of households in 23 cities, having populations of one million and above in India, is made as 8.733 million (Markandya and Murty, 2000). The beneficiary population of user benefits is assumed to constitute the urban

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Table 3. *Parameter estimates of willingness to pay function for users*

| Dependent variable: | LBID | | |
|---|---|---|---|
| R-squared | 0.333 | Number of observations: | 1,658 |
| F-statistic (zero slopes) | 74.7823 | Adjusted R-squared | 0.329 |
| *Variable* | *Coefficient* | *t-statistic* | |
| CONSTANT | −8.667210*** | −10.17430 | |
| QLOG | 1.650770*** | 25.69260 | |
| ILOG | 0.257506*** | 5.21845 | |
| ALOG | 0.220183** | 1.84446 | |
| SLOG | 0.379225*** | 5.19918 | |
| ELOG | 1.315010*** | 5.44689 | |
| VISIT | −0.115655 | −1.29187 | |
| B_STAND | −0.057098 | −0.53275 | |
| D_STAND | 0.207632*** | 3.19731 | |
| CITY1 | −0.042507 | −0.37118 | |
| CITY2 | −0.276524*** | −3.59519 | |
| CITY3 | 0.043403 | 0.41013 | |

*Notes*: See table 1.
*Source*: Markandya and Murty (2000).

Table 4. *Mean willingness to pay for non-users and users (rupees per household per annum at 1995–1996 prices)*

| *Levels of water quality* | *Bathing quality* | *1995 quality with GAP* | *1985 quality* | *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).

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 provides the estimates of annual aggregate incremental user and non-user benefits from the GAP. If the pilgrims to various ghats of the river are also considered as users of the Ganges, the users benefits could be very high, running in to several thousands of millions.[5]

*3.2. Health benefits*

The health benefits could be estimated using the cost of illness approach, dose response function, and the health production function. The dose

[5] This method of estimating benefits of hypothetical values of water quality is, to the best of our knowledge, not one that has been used before. Markandya and Murty (2000) provide a rough estimate of annual user benefits (benefits to those living along the riverbanks and to pilgrims) as Rs. 6680 million by improving the river quality to the bathing quality standard.

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Table 5. *Aggregate willingness to pay for changes in the Ganges water quality (rupees million at 1995–1996 prices)*

| *Change in water quality level* | *Non-user benefits* | *User benefits* |
|---|---|---|
| 1985 to bathing quality | 4,021.1 | 32 |
| 1985 to 1995 quality | 797.7 | 5 |
| Simulated to bathing quality | 3,986.5 | 33 |
| Simulated to actual 1995 quality | 832.3 | 6 |

*Source*: Markandya and Murty (2000).

response function and the cost of illness approaches may underestimate the health benefits from the pollution abatement, for they could not account for the expenditures incurred by the households on mitigating (using medicines, and consulting a doctor) and averting activities (using water purifiers and staying indoors) in response to environmental pollution. The household health production model accounts for these expenditures. The estimates of health benefits from the reduction in river pollution made here using the cost of illness approach could therefore underestimate health benefits.

The health benefits are estimated by a study conducted by the All India Institute of Hygiene and Public Health (AIIH&PH, 1997), Calcutta. Data were collected about the health of a sample of population living along the Ganges in the two scenarios of with and without river cleaning. Since cross-section data are used in estimating the health benefits, the data about 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 the reduction in working days lost due to illness from waterborne 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 contingent valuation method as described above. 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. There is a possibility that the willingness to pay responses of literate households in the contingent valuation survey may capture the health benefits to them along with the recreational benefits. However, care is taken while designing and implementing the CV method for measuring recreational benefits from cleaning the Ganges to avoid the possibility of willingness to pay responses from the respondents containing both health and recreational benefits.

A study conducted by AIIH&PH (1997) presents 'before' and 'after' GAP data on the health of the population living along the Ganges river. The benefits from the improved water quality from the GAP are estimated based on (a) increases in the users income due to reductions in working days lost, (b) 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 the Ganges pollution in six towns on the Ganges

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Table 6. *Health benefits from reduced loss of working days*

| *Town* | *Average no. of working days saved yearly per family* | *Regular users of the Ganges in town (no. of families)* | *Individual daily income (Rs.)* | *Total value (Rs. mn.)* |
|---|---|---|---|---|
| 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).

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 12-month periods. Using the data from the survey, the yearly benefits of improvements in water quality of the river due to the GAP were estimated in terms of increases in household incomes for each of the six study areas (where average numbers in the household are 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 6.[6] 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.

The sewage from towns and cities along the Ganges is used for irrigation by small farmers. There could be health benefits to farm workers from the GAP projects. A study by AIIH&PH of health conditions of the 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 farm worker due to these improvements. Therefore the total monetary benefit was calculated as Rs. 480,000/year/100 farm workers.

[6] The data provided by AIIH&PH were for household incomes. Since the losses of days are for person days, the value 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.

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Table 7. *Benefit of the GAP water quality improvements as measured by savings in water treatment expenditure*

| *Town* | *Population* | *Water supply* (MLD)* | *Benefit per year (Rs. mn.)* |
|---|---|---|---|
| Titagarh | 114,085 | 17.11 | 18.74 |
| Chandannagar | 120,378 | 18.06 | 19.78 |
| Nabadwip | 104,533 | 15.68 | 17.17 |
| Patna | 1,376,701 | 206.51 | 226.13 |
| Kanpur | 2,037,333 | 305.6 | 334.63 |
| Haridwar | 699,230 | 104.88 | 144.84 |
| Total | | | 731.29 |

In order to estimate the total annual health benefits of the GAP, the loss of working days in the Ganges river area are calculated as follows:

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

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 paper are for sewage workers. These benefits work out to be Rs. 4,800 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.

*3.3. 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 the 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. To reach 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. 3,000 per million litres. The results are given in table 7 and show a total benefit per year from implementation of the GAP of Rs. 731.29 million for the six towns. This indicates that in Calcutta, where water supply from the Ganges is 900 MLD (million litres per day), the yearly benefit of improved water quality through the 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

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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 with what they were before the GAP, those savings are correctly to be added to the GAP benefits. But the above cost savings are relative to a technique that is an improvement in water treatment which achieves the goals of the GAP.[7]

*3.4. Agricultural benefits*

Benefits to farmers are estimated using the data from a survey of farmers using water from sewage treatment plants (STPs) of the GAP. Benefits to farmers are estimated as the value of incremental farm output due to irrigation and savings in the cost of conventional fertilisers from making use of the partly treated water from sewage treatment plants. The GAP has 35 STPs with a capacity to treat waste water volume of 919.82 million litres a day. For estimating irrigation benefits of the 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 patterns, 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 estimate of waste water capacity per day required to irrigate 1 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 1,000 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 the 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 the GAP and non-GAP farms are respectively given as Rs. 16,837 and Rs. 9,518. Therefore, the incremental benefits per hectare of irrigated land in the GAP farms is estimated as Rs. 7,319. 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 1995–1996 prices.[8]

Savings in conventional fertilizers to the GAP farmers could be obtained by comparing the estimates of conventional fertilizers used by the

[7] An earlier reviewer of this study has noted that, for the six-cities along the Ganges 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.

[8] 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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GAP farmers and non-GAP farmers. The estimated cost of conventional fertilizers per hectare of the 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 the 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 1995–1996 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 show 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 the GAP, the total amount of sludge generated annually by the GAP projects can be estimated as 73,914.30 MT. The National Environmental Engineering Research Institute (NEERI) obtained the chemical analysis of sludge from some STPs from the Varanasi and Kanpur areas in 1991. 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. Given these estimates, annual fertilizer potential of sludge from the GAP projects can be estimated as 1,357.805 MT of Nitrogen, 375.485 MT of Phosphorous and 345.919 MT of Potassium.

The retail prices of fertilizers, Nitrogen, Dai and Phosphatic (D.A.P) and Potash are respectively given as Rs. 4,000, Rs. 12,000, and Rs. 6,000 per MT during the year 1995–1996 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 1995–1996 prices.

### *3.5. Fisheries benefits*

GAP could contribute to the increased supply of fish and reduce the risk of fish infection or contamination. For estimating the benefits from the improved fish supply from the Ganges, 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 mainly accrue 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 the GAP in the estimation of social benefits.

### *3.6. Benefits to unskilled labour*

There are employment benefits to unskilled labourers due to the GAP. Empirical studies about employment in the Indian economy show that there is surplus unskilled labour, especially in the rural or agricultural sectors. The construction and the operation and maintenance of the GAP

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projects create employment to these unemployed labourers and contribute to an increase in their real incomes. Out of total investment of Rs. 7,657.37 at 1995–1996 prices made on the GAP projects during its first phase, Rs. 1,837.77 million were paid as the wage bill to unskilled labour. Out of annual expenditure of Rs. 355.703 million on the operation and maintenance costs of the 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 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 employment of unskilled labourers on the GAP projects, first due to increased income from employment and second from the redistribution of income to the unskilled labourers belonging to the low income group in the Indian economy.

*3.7. Costs of cleaning the Ganges*

Costs to government

The total funds released by the Government of India for the investment expenditure of the GAP (under both the GAP Phases I and II) at 1995–1996 prices were Rs. 7,657.37 million during the period 1985–1986 to 1996–1997. Of the total funds released, Rs. 7,045.40 million is under the GAP Phase I and the remaining Rs. 611.97 million are under the GAP Phase II. However, the total actual investment under the GAP Phase I is Rs. 6,397.25 million. This includes Rs. 2,769.88 million in Uttar Pradesh, Rs. 2,782.94 million in West Bengal, and Rs. 844.43 million in Bihar. Table 8 also provides information about the time phasing of investment expenditures for the GAP Phase I during the period 1985–1986 to 1996–1997. These expenditures cover a large number of water pollution abatement projects contributing to cleaning up 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 Sewage Treatment Plants (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 the GAP projects. Out of a total capital cost of Rs. 7,657.37 million at 1995–1996 prices, the unskilled labour and skilled labour employed for the construction of the GAP projects amounted to Rs. 1,837.77 million and Rs. 1,684.62 million respectively. Table 8 provides details of the composition of the capital cost of the GAP in terms of domestic material, and skilled and unskilled labour.

Expenditures on the operation and maintenance of projects under GAP Phase I during the period 1986–1987 to 1996–1997 at 1995–1996 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 operation and maintenance expenditures of GAP Phase II are not available and,

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Table 8. *Domestic material, skilled labour and unskilled labour components of the capital cost of GAP (Rs. million at 1995–1996 prices)*

| *Year* | *Domestic material* | *Skilled labour* | *Unskilled labour* | *Total capital cost* |
|---|---|---|---|---|
| 1985–86 | 83.09 | 33.85 | 36.93 | 153.87 |
| 1986–87 | 310.68 | 126.58 | 138.08 | 575.34 |
| 1987–88 | 478.33 | 194.88 | 212.59 | 885.80 |
| 1988–89 | 589.84 | 240.30 | 262.15 | 1,092.29 |
| 1989–90 | 579.96 | 236.28 | 257.76 | 1,074.00 |
| 1990–91 | 452.62 | 184.40 | 201.17 | 838.19 |
| 1991–92 | 381.94 | 155.61 | 169.75 | 707.30 |
| 1992–93 | 374.01 | 152.37 | 166.22 | 692.60 |
| 1993–94 | 416.47 | 169.67 | 185.10 | 771.24 |
| 1994–95 | 181.26 | 73.85 | 80.56 | 335.66 |
| 1995–96 | 144.30 | 58.79 | 64.13 | 267.21 |
| 1996–97 | 142.49 | 58.05 | 63.33 | 263.87 |
| Total | 4,134.99 | 1,684.63 | 1,837.77 | 7,657.37 |

*Source*: Markandya and Murty (2000).

therefore, the estimates of these expenditures are obtained by assuming that the ratio of operation and maintenance costs and capital cost of the GAP Phase II is same as that of GAP Phase-I. An estimate of operation and maintenance costs of the GAP projects created so far under Phase I and Phase II is made as Rs. 480.264. Estimates of share of skilled and unskilled labour in the total operating cost of the 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 operation and maintenance costs. Table 9 provides the time phasing of operation and maintenance expenditures of the GAP, at 1995–1996 prices. Out of total operation and maintenance costs of Rs. 480.26 millions at 1995–1996 prices, skilled and unskilled labour account for Rs. 19.21 million and Rs. 81.65 million respectively as given in table 9.

Cost to industry

The international experience of river cleaning programs 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. The environmental regulation 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 the GAP and there is private investment by industries in the Gangetic basin. It is mandatory for the industries to make investments in pollution control to meet the national standards for the 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

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Table 9. *Domestic material, skilled labour and unskilled labour components of O&M cost of the GAP (Rs. million at 1995–1996 prices)*

| *Year* | *Domestic material* | *Skilled labour* | *Unskilled labour* | *Total O & M cost* |
|---|---|---|---|---|
| 1986–87 | 5.088 | 0.258 | 1.095 | 6.440 |
| 1987–88 | 10.391 | 0.526 | 2.236 | 13.153 |
| 1988–89 | 22.021 | 1.115 | 4.739 | 27.875 |
| 1989–90 | 29.693 | 1.503 | 6.390 | 37.586 |
| 1990–91 | 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).

standards provide an estimate of Rs. 0.39 per kilolitre of water treated at 1993–1994 prices (Murty *et al*., 1999). The daily cost of treating 2.6 million kilolitre 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.

**4. Estimates of social benefits of the GAP**

Estimates of time flows of benefits and costs at market prices described in the earlier section could be used to estimate the social benefits of cleaning the Ganges. For estimating the social benefits of the GAP using the methods of social cost benefit analysis of investment projects (Dasgupta, Marglin, and Sen, 1972; Little and Mirrlees, 1974) one requires the estimates of social rate of discount and the shadow prices of investment and unskilled labour for the Indian economy. The social cost of investment in the 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 the 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 a lower time preference rate for savings than the rate individuals have in the free market. Murty *et al*. (1992) provides the estimates of the social rate of discount and shadow prices of capital and unskilled labour for the Indian economy. These estimates are in the 10–12 per cent range for the social rate of discount, a 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 the market wage as the shadow wage rate.

The criteria of net present social value, internal rate of return, and the benefit–cost ratio could be used to estimate the social benefits of the GAP.

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Table 10. *Estimates of present value of benefits of cleaning the Ganges for various beneficiaries at market prices and with income distribution effects (Rs. million at 1995–1996 prices)*

| | | *With income distribution effects* | |
|---|---|---|---|
| | *At shadow prices* | $\varepsilon$ =1.75 | $\varepsilon$ =2.0 |
| 1. Users | 29.11 | 2.79 | 1.98 |
| 2. Non-users | 6,871.03 | 439.74 | 295.45 |
| 3. Farmers | 574.93 | 1,709.84 | 1,997.88 |
| 4. Health beneficiaries | 826.93 | 2,549.29 | 2,873.58 |
| 5. Fishermen | NA | NA | NA |
| 6. Unskilled labour | 1,919.42 | 5,708.36 | 6,670.00 |
| 7. Industrial units | −1,504.59 | −144.44 | −102.31 |
| 8. Government | −4,569.32 | −4,569.32 | −4,569.32 |
| 9. Net present value | 4,147.51 | 5,696.26 | 7,167.26 |
| 10. Benefit–cost ratio | 1.68 | 2.21 | 2.53 |

*Note*: Rate of discount is taken as 10 per cent. The cost to the government is the present value of costs incurred up to the year 1996–1997.
*Source*: Markandya and Murty (2000).

Considering the estimates of benefit and cost flows of the GAP during the period 1985–2020, table 10 provides estimates of present value of benefits and costs to various agents in the Indian economy from cleaning the Ganges at a 10 per cent rate of discount. The net present value of the GAP at a 10 per cent rate of discount is estimated as Rs. 4,147.51 million at shadow prices of investment and unskilled labour. The internal rate of return on investments on the GAP is as high as 15.4 per cent. The benefit–cost ratio is estimated as 1.68.

The pollution free Ganges provides benefits to both rich and poor people. It is a source of livelihood to fishermen, farmers, and to the people using it for drinking and bathing. Unskilled labour get 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 distribution weights to benefits accruing to various classes of beneficiaries from the Ganges are available, the social benefits from 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)

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

where

$W$: Social welfare function
$Y_i$: Income of individual $i$
$\varepsilon$: Elasticity of social marginal utility
$A$: a constant

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Table 11. *Estimates of income distributional weights for the incomes of beneficiaries from cleaning the Ganges*

| *Beneficiary group* | *Annual per capita income (Rs.)* | *Income distributional weights* | |
|---|---|---|---|
| | | $\varepsilon = 1.75$ | $\varepsilon = 2.00$ |
| Unskilled labour, farmers and health beneficiaries | 5,000 | 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 | 9,321* | 1.000 | 1.000 |

*Note*: 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 Gross Domestic Product in 1994–1995.

The social marginal utility of income is defined as

$$\frac{\partial W}{\partial Y_i} = AY_i^{-\varepsilon} \tag{2}$$

Taking per capita national income, $\bar{Y}$ as the numéraire, and giving it the value of one, it can be written from (2)

$$\frac{\partial W}{\partial Y_i} = A\bar{Y}^{-\varepsilon} \equiv 1$$

$$A = (\bar{Y}^{\varepsilon}) \tag{3}$$

Substituting $(\bar{Y}^{\varepsilon})$ for $A$ in (1), the social marginal utility of income to the individual $i$ $(SMU_i)$ can be written as

$$\frac{\partial W}{\partial Y_i} = SMU_i = \left[\frac{\bar{Y}}{Y_i}\right]^{\varepsilon} \tag{4}$$

The value of $\varepsilon$ is in fact the weight to be attached to the costs and benefits to group $i$ relative to the costs and benefits to the person with income equal to the national *per capita* income. In order to compute these weights, data about $(\bar{Y})$, $Y_i$, and $\varepsilon$ are needed. Some recent studies in India about the estimates of $\varepsilon$ have suggested a range of 1.75–2.0 for its value (Murty *et al.*, 1992). The Economic Survey, 1995–1996, Government of India suggests an estimate of per capita Gross Domestic Product for the Indian economy of Rs. 9,321 at 1995–1996 prices. The estimates of social marginal utility for various beneficiaries from cleaning the Ganges are given in table 11.

The estimate of net present social value of the GAP increases from Rs. 4,147.51 million to Rs. 5,696.26 million while the benefit–cost ratio goes up from 1.68 to 2.21 if income distributional benefits are accounted.

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**5. Sustainability of processes of cleaning the Ganges**

A number of different mechanisms can be considered to raise the resources for sustaining the cleaning of the Ganges. They are a polluter-pays 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 kilo litre 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 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 to set 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 be in fact possible to have a combination of an effluent tax and a voluntary payment scheme of the kind outlined above. The details have, of course, to be worked out, but the prospects of success are good.

**6. Conclusion**

Many environmental and development issues have to be dealt with in the river cleaning programs. They underscore the importance of co-operation of riparian states against non-co-operation 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 the river cleaning program including the program 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 the institutions facilitating local community participation.

There are multiple benefits from the river cleaning program. As shown in this paper, the estimation of these benefits requires the market and non-market valuation. Due to data problems, all the benefits from the GAP could not be estimated. With whatever benefits quantified, the GAP has significant positive net present social benefits at 10 per cent social rate of

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discount for the Indian economy. The internal rate of return is as high as 15 per cent.

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

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