Sustainability of Urban Water Supply and Sanitation in Dryland Areas

A Study of Indore City

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The attainment of financial, environmental and social sustainability of urban service provision has become problematic nowadays. Within urban services, the supply of water and its disposal after use have become very important because water has to be brought from distant sources and the waste water needs to be treated before being discharged into natural waterbodies, both of which are very costly propositions. In dryland areas, which are physically water scarce and constitute some 70% of the country, the problem becomes even more acute. The water supply and sanitation services in the city of Indore in Madhya Pradesh are critically reviewed, and suggestions are made for alternative measures for a more equitable and sustainable water management system.

This paper was presented at the conference of the Indian Society of Ecological Economics that was held from 4–6 January 2016 in Bengaluru. The paper has benefited from the suggestions of many people on earlier drafts, including those of an anonymous referee.

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The first United Nations (UN) Conference on Environment and Human Settlements held in Vancouver in 1972 recognised the need for adequate provision of sustainable and equitable access to municipal services required to make cities healthy and liveable (Mahadevia 2003). This was called the "brown agenda" (McGrahanan and Satterthwaite 2000). In 1987, the World Commission on Environment and Development—constituted by the UN in 1983—put forward the concept of sustainable development as development which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (UNO 1987). Subsequent to this, the issue of environmental sustainability and equity assumed importance, and in the field of urban development this was named the "green agenda" (McGrahanan and Satterthwaite 2000).

Reconciling the green and brown agenda and ensuring the attainment of financial, environmental and social sustainability and equity of services is currently the goal of urban development. Within urban infrastructure and services, water supply and sanitation (WSS) have become important aspects of planning and management, because water has to be brought from distant sources and waste water needs to be treated before being discharged into natural waterbodies or rivers. In dryland areas, which are physically water-scarce and constitute 70% of the country (Kumar et al 2008), the problem becomes more acute as the costs associated with setting up and running centralised WSS services are prohibitively higher. Given the financial, social and environmental problems that are increasingly plaguing centralised systems, new hybrid and decentralised systems have been developed and implemented across the world. One such system has been described below.

Water Sensitive Urban Design

The concept of Water Sensitive Urban Design (WSUD) is defined as "an approach to urban planning and design that integrates the management of the total water cycle into the urban development process" (SASTORM 2011). It includes: (i) integrated management of groundwater, surface run-off (including stormwater), drinking water and waste water to protect water-related environmental, recreational and cultural values; (ii) storage, treatment and beneficial use of run-off; (iii) treatment and reuse of waste water; (iv) using vegetation for treatment purposes, water-efficient landscaping and enhancing biodiversity; and (v) utilising water saving measures, within and outside domestic, commercial, industrial and institutional premises, to minimise requirements for drinking and non-drinking water supplies.

Thus, by reusing storm water through appropriate water-harvesting techniques involving both surface and aquifer storage and the treatment and reuse of waste water, the need for expensive drainage and water supply systems is reduced considerably. The design of buildings is done in such a way as to save on water use and increase water storage and reuse. In the process, the environment is also conserved as extensive soil conservation and plantation activity is undertaken in the unbuilt environment. This approach can bring about substantial benefit at less cost, compared to further investments in solutions that rely only on technological fixes for water supply and waste water management problems. In the urban water management context, this involves an optimal use of both groundwater and surface water sources and feasible recharging, and reuse of storm and waste water.

Consequently, there is a need to study, in depth, the financial, environmental and social sustainability and equity of WSS services in cities in the dryland areas. This paper reviews the WSS infrastructure and services in the city of Indore in Madhya Pradesh (MP), based on a detailed study of the records and budgets of the Indore Municipal Corporation (IMC) and other sources. The key research questions addressed are: How viable are the existing and proposed WSS services in Indore given the natural and financial resource endowment of the IMC, and the economic situation of the population, in general, and the poor, in particular? Further, what are the possible improvements in WSS provisioning and governance in Indore?

Methodology

This is a desk study based on a critical review of the following secondary sources: (i) Study of town plans, detailed project reports and performance reports of various projects undertaken with funding from the Asian Development Bank (ADB), Jawaharlal Nehru National Urban Renewal Mission (JNNURM), Department for International Development (DFID), and the United Nations Human Settlements Programme (UN-Habitat); (ii) analysis of the annual budget documents and WSS records of the IMC; (iii) comparison of the cost of WSS services as calculated from the budget data with the consumption expenditure data of the National Sample Survey Office (NSSO) to determine the affordability and equity of these services; (iv) review of literature on alternative WSS management in India and abroad.

Demographics

The population dynamics of the district are given in Table 1. In 2001–11 the district population grew by 36.8% and that for the municipal area, by 30.2%. The growth rate of population in Indore district in 2001–11 is much greater than that for the whole of India for the same period, which is 31.8% (GoI 2011). The female–male sex ratio in 2001 in Indore district was 912 while the density was 663 persons per square kilometre (sq km). The city population density is far higher at 15,070 persons per sq km. The Indore Development Plan (IDP) 2021 does not disclose the methodology adopted for projecting the population growth in the future, but the figures indicate an assumed average decadal growth rate of 40.7%, which is much higher than those actually prevailing. In 2011, the population density of Indore district was 839 persons per sq km, with a sex ratio of 924.

Table 1: Population Dynamics of Indore

Area	2001	2011	2021
Indore district	24,65,827	33,73,251	46,95,921*
Indore municipal area	15,06,062	19,60,631	31,17,548*
Indore planning area 2021	16,98,474	25,34,685	35,66,994*

*Projections.
Source: GoMP (2008).

The IDP 2021 estimates the population that was living in slums in 2001 to be 4,85,585 or 30.4% of the total. However, a detailed citywide household survey carried out in 2006 found that there were 604 slum clusters in Indore city with 1,76,545 households, or an estimated population of 8.8 lakh, if we conservatively assume an average household size of five (WaterAid 2006). This is close to 51% of the extrapolated population in 2006. These people live mostly in hutments of less than 35 sq metres (George et al 1998). Since provision of services to these slum clusters, especially WSS services, are an important aspect of urban planning, this underestimation of the slum population seriously affects the relevance of the planning process.

There is a considerable amount of migration into the city, especially among the poorer sections residing in slums. This also creates additional demands on the infrastructure. There is very little provision of WSS services for this migrant population. However, there are no reliable data regarding this phenomenon that crucially impacts urban planning and development, and it has not even been considered in drawing up the 2021 Development Plan.

Geography and Hydrogeology

The urban planning area under the Indore 2021 Plan is 50,469 hectares extending roughly between 75°47' and 75°57' E Longitude and 22°37' and 22°47' N Latitude situated on the southern edge of the Malwa plateau, with the city more or less in the centre. The maximum temperature is about 45°C in summer and the minimum temperature about 7°C in winter. The mean annual rainfall is 1,000 millimetre (MM), and most of it comes in the months of June–September. The predominant rocks in the district are the Deccan Traps. The water-bearing properties of these rocks vary widely. The weathered zones and secondary porosities of the massive basalts and the minutely connected and partially filled vesicles of the vesicular basalts determine the occurrence, movement and storage of groundwater. These are the potential aquifers. The run-off is very high due to low permeabilities of basalts topped by clayey black cotton soils and the natural recharge is low. The vesicular zones occurring below a depth of 30 metres (m) have poor water-yielding capacity. The thickness of the weathered formation encountered ranges between 6 m and 30 m. The thickness of the water-bearing zones is generally between 1 m and 3 m (CGWB 2015a).

Central Ground Water Authority (CGWA) has declared Indore a severely exploited area with regard to groundwater, and directed the district collector under the provisions of the Groundwater (Control and Regulation) Act, 1992 to ban any further tube wells boring in the city of Indore (*Hindustan Times* 2009a). However, in the absence of adequate surface water supply, this ban has not been imposed and the number of tube wells continues to increase and the static reserves of groundwater built up over thousands of years are being depleted. The situation is particularly grave in Indore city, where a survey carried out by the IMC revealed that there were 51,000 tube wells in the municipal region in 2010 (*Dainik Bhaskar* 2010). This had gone up from 13,400 recorded in 2004.

Water Supply Situation

The total installed water supply capacity for Indore in 2015 according to the IMC (2015) was 481 million litres per day (MLD) from four sources and their actual respective contributions in 2015 were as follows: Three phases of Narmada—360 MLD; Yashwant Sagar Reservoir on Gambhir River—70 MLD; Bilawli Tank—9 MLD; tube wells, open wells and handpumps—42 MLD.

This total water supply of 481 MLD as claimed by the IMC requires some critical analysis to verify its authenticity. The first two phases of the Narmada river supply each have an installed capacity of 90 MLD, arriving at a total of 180 MLD. At the behest of the ADB, meters were installed on these two phases in December 2008 to conduct a water audit (Khan 2008). It was found that 8 MLD was lost in pumping the water from the intake well up to the filtration plant. Another 55 MLD was lost or was unaccounted for in the transit of the filtered water by pumping—over a distance of 20 km and a height of 600 m—to the Backpressure Tank at Wanchoo Point. Thereafter, as the water flowed through gravity over a distance of 50 km to the city of Indore and then through the distribution networks, another 31 MLD was lost or was unaccounted for (*Hindustan Times* 2011a). Thus, the actual accounted for supply to households from the older phases was only 86 MLD. This implies a huge loss due to technical inefficiencies like bad maintenance and out-and-out theft.

The new third and fourth phases built with the ADB loan has not been metered, but assuming a nominal 10% technical loss because it is a new pipeline and a similar 10% distribution loss, the volume of water available to households from the third and fourth phases was 144 MLD instead of the installed capacity of 180 MLD. So the total Narmada water supply was actually 230 MLD against an installed capacity of 360 MLD. Similarly, the supply from Yashwant Sagar was actually 40 MLD against the installed capacity of 70 MLD (IMC 2015). However, even this level of supply resulted in the reservoir drying up by the first week of May and thereafter there was no supply during the crucial summer period. The contribution from the Bilawli Tank of 6 MLD against an installed capacity of 9 MLD can be taken as given, but here too, the supply stops from the first week of May due to the reservoir drying up. The number of operational IMC tube wells borings was 3,500 or so. Given the shortfall in IMC surface water supply, the figure of 42 MLD is likely to be an underestimate for groundwater supply from these borewells, wells and handpumps, but in the absence of other data, this value has to be accepted. Like in the case of the Yashwant Sagar and Bilawli supply, the tube wells supply too went down in summer as some wells dried up. So the piped water supply is only 315 MLD and this reduces to 285 MLD in the peak summer months when extra tanker supply has to be provided from private groundwater sources. About 10% of the total accounted for supply goes to bulk consumers.

This shortfall in the supply of water and its high cost has evidently resulted in extremely poor supply to the slums. A survey conducted in 2006 revealed that 72% of slum households in Indore did not have access to piped water supply from the IMC and have to depend on standpipes, public borewells or wells, and 4.7% from among these do not even have access to safe water sources. Even the 28% that had access to piped water supply complained of irregular and inadequate supply of about half an hour every alternate day. And even among these, 20% said that their taps were completely dry and they had to rely on standposts instead (WaterAid 2006). This leads to a loss of work hours for fetching water and also because of affliction with water-borne diseases due to lack of sanitation. This affects women more because of the patriarchal gendered division of labour, which puts the responsibility for home care work on women.

The 2011 Census population of Indore Municipal Area was 19,60,631. This can be extrapolated to be 21,58,000 in 2015. However, this piped-water supply was being provided by the IMC to only 54% of the population ostensibly at 234 litres per capita per day (lpcd) on an average, which compares favourably with the norm of 135 lpcd as given in the government guidelines (GoMP 2010). However, in reality, much of this water is lost due to leakages and theft which are unaccounted for. But, the rest of the population mostly in the slums are getting only 46.6 lpcd. Thus, there is a huge difference between the richer and poorer sections of the populace as regards access to water and the overall average water supply is 145 lpcd. However, in the absence of metering it is not possible to know the actual supply at the household level. These results have been tabulated in Table 2.

Table 2: Water Supply by Indore Municipal Corporation, 2015

Sl No	Mode of Water Supply	Population	Household Water Supply (MLD)	Supply per Capita (lpcd)
1	Piped water supply	11,65,000	273	234
2	Supply by tankers, tube wells, open wells, standpipes and handpumps	9,93,000	42.0	46.6
3	Total water supply	21,58,000	315	145

Source: Author's calculations based on the IMC and Census 2011 data.

A study conducted by The Energy and Resources Institute, New Delhi (TERI 2006), used some of the rough data provided by the IMC—in the absence of metering and a proper inventory of the distribution system—to calculate an Infrastructure Leakage Index (ILI) of 404.3 for the IMC water supply. This index is the ratio between the actual water losses taking place in the system to the minimum unavoidable water losses in a water supply system, and is a measure of the efficiency of the system. Obviously the lower its value the better, and ideally the estimate should range from two to six. The extremely high value of the ILI for the IMC is an added proof of the severe inefficiency of the system. The values for water availability used for this calculation are much higher than those actually prevailing which have been used in the analysis here, and so the actual ILI is even higher, indicating a higher inefficiency.

Water Supply Finances

A detailed estimation of the costs of water supply has been done to get a proper idea of the finances of the IMC in this regard. The actual expenditures for 2014–15 and the extrapolated population data for this year have been used along with the actual water supply volumes in Table 3.

The costs have been estimated separately for the various sources for comparison. It has been assumed that the water that is lost and unaccounted for is non-revenue water for which the IMC does not get any payment. For calculating the per unit volume cost of water it is assumed that there is supply of water on all 365 days from all sources even though, in reality, there are large gaps in supply, most glaringly in the Yashwant Sagar, Bilawli and groundwater supplies, which dry up in peak summer. It is also assumed that the average household is of five members. The monthly costs have been worked out for the norm of 135 lpcd supply. Two scenarios have been estimated. The cost of the water from the Narmada supply was the highest at ₹25 per 1,000 litres mainly due to high electricity charges, the ADB loan and interest repayment. It was lowest for the Yashwant Sagar and Bilawli supply at ₹3 per 1,000 litres, and that for the tube wells supply was ₹14 per 1,000 litres. The average cost for the total water supply was ₹21 per 1,000 litres. The monthly average cost of supplying a five-member household the standard supply of 135 lpcd was ₹425. However, the average piped water supply to 54% of the population which was being charged for its supply was 234 lpcd. The average cost of this supply was ₹21 per 1,000 litres as calculated in Table 3. So the actual average cost to the IMC of piped water supply for a family of five in 2015 was higher at ₹737 per month.

There were 1,73,603 registered domestic water connections which covered 54% of the population of the city in 2015. They were being charged at rates varying from ₹200 per month for a half-inch connection, to ₹4,200 per month for a one-and-a-half inch connection. The average water tax per connection in 2015 according to the IMC was ₹225 and so the total annual water tax collection from the registered users should have been at least ₹47 crore (1,73,603*225*12).

However, the actual collection was only ₹27 crore resulting in massive under-collection. The bulk supply rate charged by the IMC was ₹30 per 1,000 litres for industries and ₹25 per 1,000 litres for commercial establishments like hotels. The total registered bulk supply was 21 MLD and so the bulk charge collection should have been at least ₹19 crore. Instead, the actual collection was only ₹8 crore. Thus, here too there was under-collection of more than 50%. So not only was there a very high proportion of loss and unaccounted water, but the revenue for the accounted water was also not being collected properly by the IMC. Further, even the state and central government agencies are not paying their water dues and have run up bills of over a lakh rupees each, and the total outstanding is close to ₹100 crore (*Hindustan Times* 2009b).

Table 3: Indore Municipal Corporation Cost of Supply of Piped Water in 2015

Type of Supply		NWS*	YSB**	GW***	Total
Costs in ₹ crore	Salaries	15	2.5	2.5	20
	Operations and maintenance	12	0.5	4	16.5
	Electricity	130	2	15	147
	Capital and interest payments	50	0	0	50
	Total	207	5	21.5	233.5
Daily water supply in MLD		230	43	42	315
Average cost of water in ₹/1,000 litres		25	3	14	21
Monthly cost of 135 lpcd for a household of 5 (₹)		506	61	284	425

*Narmada Water Supply, **Yashwant Sagar and Bilawli, ***Groundwater.
Source: Calculated from IMC Budget 2012–13 (IMC 2013) and IMC Water Supply Data.

ADB Water Supply and Sanitation Project

The ADB gave a loan to implement the third phase of the Narmada water supply in Indore which involved adding another 360 MLD to the water supply and the construction of the accompanying overhead tanks and distribution system. The ADB sanctions a loan only if the economic internal rate of return (EIRR) and the financial internal rate of return (FIRR) are suitable (ADB 2004). The EIRR reflects the economic returns from the project to the people of Indore as a whole, while the FIRR reflects the financial returns to the IMC. A project should be chosen from a menu of options by comparing their EIRRs and selecting the one with the highest EIRR. Subsequently, the FIRR of this selected project should be checked to see whether it is financially viable. This is because in calculating the EIRR many non-tangible benefits are also expressed in economic prices for quantification, whereas in reality they do not contribute to the financial cash flows. The ADB discarded the groundwater option altogether, stating that the area is semi-arid and natural recharge is not assured, without exploring the possibilities of artificial recharge of storm water and the treatment and reuse of waste water. It then considered only the augmentation of water supply from the Narmada. So, only different options within surface systems were evaluated.

For the calculation of the EIRR, a sample contingent valuation survey was conducted among the citizens to quantify the non-monetary benefits of getting a good supply of water, defined as 100 lpcd for in-house connections and 75 lpcd for standposts. The respondents were asked to compare the benefits of the enhanced water supply with the prevailing dismal scenario, which would soon lead to a water crisis and jeopardise their immediate household existence as well as the continuance of Indore. The EIRR for Indore came out to be a healthy 16.5% (ADB 2004). Consequently, the loan for the development of the third phase of Narmada water supply was sanctioned.

The sewerage and storm water drainage augmentation project funded by the ADB involved the construction of a primary network of 187.4 km at a cost of ₹442 crore. A secondary network of 265 km was also planned. Two sewerage treatment plants of total capacity 245 MLD were planned of which one is ready but due to the fact that the sewerage system was not yet working at full capacity, this plant was treating only 78 MLD of sewage (Khan 2012).

Affordability of WSS Services

The ADB (2004) had also calculated that the combined enhanced WSS charges would be within 4%–5% of household expenses and so had deemed them to be affordable. For this, the monthly charge was assumed to be cumulatively ₹125 per household in 2004 and a multiplier of 1.1 at 10% annual inflation rate was used. Thus, the total monthly charge per household for WSS in 2015 as per the ADB calculation would be ₹357. As we have seen in the section on water supply situation earlier, the actual monthly cost of water supply for the IMC to be recoverd from the water charges paying households was ₹737 in 2015 if the cost of non-revenue water is also taken into consideration. The monthly chargeable sewerage and sanitation cost per household for the IMC came to ₹200. Thus, the total WSS charge per household for the IMC came to ₹937 in 2015.

The average urban monthly per capita consumer expenditure in the 66th round of the NSSO (2011) survey for MP was ₹1,666. Assuming a household of five persons, this gives an average monthly household consumer expenditure in 2010–11 of ₹8,330. Assuming an inflation rate of 10%, the average household consumer expenditure in 2015 would be ₹13,415. Thus, the proportion of the combined water cum sanitation tax is—7% (100* ₹937/₹13,415) of the average monthly household expenditure.

The proportion of households who had a monthly per capita consumer expenditure less than the average as per the NSSO survey was 70%. If we assume that 30% of the population of Indore who are living in slums will be exempted from paying the water charges, then a fairly large 40% of the population would have to pay 7% or more of their household expenditure for WSS charges if full costs were to be recovered. Thus, a considerable section of the population of Indore would have found it difficult to meet the actual costs of WSS that were being incurred by the IMC in 2015. Therefore, the ADB's claim based on its analysis that the WSS charges would be affordable, is not substantiated by reality.

Critique of ADB WSS Project

The ADB, in its own appraisal review, had found that the technical, managerial and financial operations of the existing two phases of the Narmada water supply were severely inadequate and that consequently, they were suffering from huge revenue losses. Nevertheless, the possibilities of hybrid local ground and surface water development were ignored totally and the third phase was sanctioned. The assumption was that the losses in the water supply system would be substantially brought down as a result of better technical and managerial practices reducing them from the previous levels drastically. This expectation has been belied as has been demonstrated by the foregoing analysis.

Moreover, the cost of power has gone up much more than was envisaged in the calculations of the ADB. A sensitivity analysis conducted in the EIRR estimation showed that slippage in completion dates of the project, cost overruns and failure to improve the operation and maintenance and cost recovery would greatly reduce the EIRR. These negativities have all occurred and so the project has in reality become unviable. Crucially, the new distribution system for the third phase is not in place and so the same old leaky system is being used for a higher supply, leading to frequent breakdowns and higher losses.

The FIRR was calculated as 5.6% on the assumption of the water tax going up from ₹60 in 2003 to ₹190 in 2009. Thereafter metering was to be introduced in all old connections and new ones were to be compulsorily metered. Simultaneously, the coverage and collection efficiencies were to be 75% and the non-revenue water was to be only 20%. However, none of these assumptions were true as we have seen in the financial analysis done earlier and in reality, huge losses and outstanding dues were being run up. These losses and dues have increased even more as the full annual loan repayment burden of ₹59 crore has started from 2015 onwards.

The ADB had suggested that to improve the operation and maintenance efficiency, and recovery of costs, the distribution of water under the new phase should be done as a public–private partnership (PPP) enterprise wherein the IMC would supply water in bulk to an overhead tank and the further distribution and charge collection would be undertaken by a private franchisee. There would be 24x7 water supply with metering to improve efficiency and cut down on losses. The Rajendranagar locality was chosen as the first area for this new mode of water supply. However, the project got delayed as one of the bidders had contested the award of the contract to another franchisee in the high court. Though the matter was resolved, work is yet to start. Even so, as the project was envisaged, the capital costs of construction of overhead tanks and the laying of distribution lines would have to be borne by the IMC and the franchisee would only recover the operation and maintenance costs through user fees (*Hindustan Times* 2010). This would further undermine the financial viability of this model as the infrastructure cost would have to be borne from other sources. There is obviously no provision for the slums in this PPP model and so, given the high costs of water supply, the availability of water has gone down drastically in the slums.

The Sanitation Situation

The sewerage, storm water and solid waste management systems in Indore are in total disarray. There is a sewerage system from 1931 in some parts of the city which was augmented partly later and it covers only 20% of the present enhanced municipal area. This system is leaking heavily due to broken pipes and it contaminates the groundwater and sometimes even the water supply which is also being done through pipes that are broken in many places. Mostly, the waste water is released into the natural drainages which are unlined nalas of about 200 km in length and these lead to the Khan and Saraswati rivers, which have become foul-smelling nalas. The Biochemical Oxygen Demand (BOD) level of the Khan river in the stretch downstream of Indore to its confluence with the Shipra river is 65–120 mg/litre against the norm of 3 mg/litre for open, clear water sources (CPCB 2015). This means that in Indore city itself the water in the nalas have a much higher BOD level. There is no storm water drainage in the city and many of the smaller natural drainages have been built up and this obstructs the flow of storm water which collects on the roads leading to severe waterlogging in the monsoons.

The ADB loan and the JNNURM grants together have provided for capital investments towards a citywide sewerage system, storm water drains, sewage treatment plants, solid waste collection and an incinerator and landfill. The solid waste collection is only about 60% of the total waste generated which was about 1,000 metric tonnes daily in 2011. The IMC has adopted a solid waste management plan that involves door-to-door waste collection, construction of intermediate transfer points, construction of landfill sites and an incinerator at the Devguradiya trenching ground (*Hindustan Times* 2012). However, none of this has materialised yet. The solid waste collection was outsourced to a private party which neither collected the waste properly nor did it manage the trenching ground in a scientific manner as waste was being incinerated in the open. The contract has recently been terminated.

The sewerage, storm water and solid waste management finances were also in dire straits. The actual receipts of drainage and sanitation tax in 2015 were ₹35 crore resulting in a huge shortfall of 65%. The corresponding actual expenditures were ₹4 crore for sanitation and solid waste conservancy and ₹4.5 crore for sewerage and storm water disposal. The salary costs were ₹49 crore. Thus, the total actual waste management costs were ₹57.5 crore which were far more than the actual receipts. An important part of waste water management is the recharge of storm water. A water recharge and plantation tax is collected for this purpose. The budget estimate in 2015 was ₹6 crore and the budgeted expenditure for recharging and plantation was ₹5 crore. However, the actual receipts in 2015 were only ₹4 crore and the actual expenditures were ₹3 crore.

Like in the case of water supply, the under-performance in the sewerage and sanitation sector adversely affects the poor in Indore. Currently, the 604 slums described earlier are extremely ill-served as far as sanitation services are concerned. According to the survey cited earlier, the proportion of households in slums without toilets in Indore was 77%, the proportion of slums without community toilets was 80% and the proportion of slums that get waterlogged in the monsoons was 78% (WaterAid 2006). The waterlogging is mainly due to the clogging of drains with solid waste which is not collected regularly from these areas. There are provisions in the JNNURM, the ADB plan and other projects for slum improvement ranging from water supply, sewerage, storm water drainage and solid waste collection, but these are not being implemented (*Hindustan Times* 2011b).

The lack of proper sanitation services has meant that the poor have to resort to open defecation. The more affluent households that are not connected to the limited sewerage system have to rely on septic tanks. These septic tanks are not properly constructed and release their untreated water into the ground, thus polluting the groundwater. Tests carried out by the IMC on samples of tube well water have shown that most of them are contaminated. Even for the Narmada water supply, 10% of the samples were found to be contaminated, indicating that ingress of polluted water is taking place in the distribution network (*Hindustan Times* 2009c).

An Alternative WSS Scenario

The foregoing discussion has made it clear that there is an urgent need to explore other systems of WSS for Indore than the one that has been adopted to date. Even if the technical inefficiencies and the loss of water are controlled, the problem of the burgeoning electricity bill for Narmada water supply as also for sewage treatment will always remain.

Recharging of groundwater aquifers in Indore: As we have seen in Table 3 it is far cheaper to source groundwater and surface water locally in Indore than surface water from the Narmada. In fact, if a proper water inventory of all the groundwater being sourced in Indore by private parties for domestic and commercial supply is done, it may well turn out that it is more than the surface water supply. However, due to unplanned pumping of groundwater and lack of artificial recharge, over-exploitation has taken place. It is in this context that solutions that incorporate extensive water recharging and waste water treatment and reuse have to be explored for a sustainable hybrid ground-cum-surface water combination. One such proposal has been given by the hydrogeologist Sudhindra Mohan Sharma (Mekaad 2009). There are locations within the IMC area where there are substantial fractures in the deep aquifer layer at a depth of about 40 metres. The normally impervious basalt rock in this layer can absorb and store large quantities of water in these fractures. Thus, if the rain water in the catchment of these fractured zones is collected and channelled to these areas, and then filtered and recharged into the fractures through vertical shafts, then cumulatively, a reserve that can yield 65 MLD of water throughout the year can be created within the IMC area itself. The cost of such a decentralised recharge system is far less than laying a network of underground storm water drains throughout the city.

In addition to this, there are already rules that all buildings of area more than 140 sq mt must have water recharging systems in place so that all the storm water is filtered and recharged within these building premises in a decentralised manner (GoMP 2010). However, these rules are not being followed. The cost of installing a water recharge system is about 3% of the total building cost and it goes down proportionately as the size of the building increases, yet this is not being done. The benefits in terms of obviating the need for extensive centralised storm water drainage systems and increasing the groundwater availability far outweigh these costs. Moreover, since these costs will be borne by the building owners themselves, it is a progressive measure wherein those with better economic capacity are made to bear the costs of WSS directly without burdening the IMC.

The Central Groundwater Board has prepared a detailed artificial recharge master plan for the whole of the country so as to replenish the available groundwater storage capacity. The details of the measures to be adopted in the Gambhir and Shipra river basins which form the catchment of Indore city, have been given in this document (CGWB 2015b). If this plan were to be implemented, then the availability of groundwater in the whole of the catchment of Indore city would be improved considerably resulting in the people in rural areas desisting from stealing water from the Narmada pipeline as they are doing at present. Moreover, surface waterbodies could be built in greater numbers to provide water sources like the Yashwant Sagar and Bilawli reservoirs. The potential for harvesting and recharge in the Indore Planning Area of 505 sq km itself is 1,038 MLD which can easily take care of the water supply requirements of the city.

Treatment and reuse of waste water: Then, there is the issue of treatment and reuse of waste water. As with storm water, so with waste water it is much cheaper to treat and reuse or recharge it in a decentralised manner. The Dhas Gramin Vikas Kendra in Indore has installed such a decentralised system in its office premises in which the bathroom and kitchen waste water is filtered through a soak pit and recharged into the ground with a BOD of less than 30 mg/litre which is the permissible limit (Pillai 2012). The toilet waste water is first directed into a septic tank. This septic tank has an aerator installed in it that causes aerobic digestion of the waste to take place. Thus, the inlet water which has a BOD of about 500 mg/litre is treated by the aeration process, resulting in a BOD of about 55 mg/litre of the water flowing out of the septic tank. This water is then filtered through a soak pit and the final water that seeps into the ground has a BOD within the permissible limit of 30 mg/litre. The installation cost of this system is less than 1% of the total building cost, while the running cost of the aerator is only ₹2/1,000 litres/day of toilet sewage. Moreover, due to the oxidation of sewage through aeration, there is no generation of sludge and foul-smelling gases. Most importantly, the need for a centralised underground sewer system and sewage treatment plants—which are expensive to construct and maintain—can be done away with. Over and above this, all the waste water, which constitutes about 90% of the potable water supplied, is recharged into the ground enhancing the groundwater availability. The greater availability of groundwater will mean lesser use of electrical energy, which in turn means the lesser production of greenhouse gases. Thus, this alternative system will also have a positive climate change mitigation impact. There is also the option of treating the waste water a little more and reusing it for flushing of toilets and gardening which together constitute close to 47% of the water use (CPHEEO 1999). There are currently no city-wide initiatives in this regard anywhere in India, but some residential layouts are implementing these ideas in several cities. One such successful initiative is the Rainbow Drive Layout in Bengaluru (Biome Environmental Solutions 2010).

Equitable and sustainable WSS for Indore: Thus, by using the WSUD principles described earlier, it is possible to design a hybrid ground-cum-surface water system of water supply. This will be augmented by storm water recharge and waste water treatment, and recharge and reuse, done in a decentralised manner, which is much more sustainable in financial, social and environmental terms. This kind of hybrid alternative system has also been advocated by a committee formed to recommend national sustainable habitat standards for the urban water supply and sewerage sector under the National Mission on Sustainable Habitat (NMSH 2011). Instead of relying on taxes, user charges and grants to fund hugely expensive centralised systems, this alternative system would put the onus on the more affluent citizens, corporations, private institutions and government institutions, who are all in possession of a considerable portion of urban land to tackle their water supply and waste water disposal needs in a decentralised manner.

Finally, there is the contentious issue of the high electricity charges of the Narmada water supply. The daily consumption of electricity for the Narmada water supply is around 8 lakh kilowatt-hours (KWH) of high tension power which is equivalent to a power demand of 33 megawatts (MW). A considerable portion of this demand, if not all of it, can be met by solar power. The solar insolation available in western MP and the number of clear days roughly give a requirement of about 30 hectares of land area and about ₹6 crore capital cost for setting up solar panel arrays to produce 1 MW of electricity (Solar Mango 2018). Thus, the total requirement is about 1,000 hectares of land and ₹200 crore. The IMC water works already possess the necessary land and, in fact, by covering the siltation tanks with solar arrays, evaporation loss would be prevented, in addition to getting clean development mechanism credits.

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