# TOOL KIT FOR INTEGRATED URBAN WATER MANAGEMENT

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## Preface

The concept of integrated urban water management (IUWM), which is an extension of the concept of Integrated Water Resources Management for urban areas, is of recent origin. There are a few developed countries which actually practice IUWM in its entirety. In India, operationalizing of IUWM concepts is cities still in its early stage. In contrast to the traditional approaches to planning urban water systems which largely focus on planning and design of supply sources, water distribution, and sewerage collection and disposal infrastructure, IUWM takes several aspects of water management into consideration. They include demand side and supply side potentials of meeting the water requirements in urban areas, the cost effectiveness of various interventions, equity in access to water supplies, environmental sustainability of water resource systems and other sustaining logistical elements.

Planning urban water management interventions involves complex considerations of a wide range of physical, socio-economic, administrative, institutional and political characteristics influencing the performance of water systems in urban areas. Indian cities and towns display wide heterogeneity in these characteristics. Hence it was logical to discuss interventions for certain 'urban typologies' that exist in India, wherein each one represents a unique combination of features vis-à-vis these characteristics. Matching typologies with new technological choices and social and management institutions is vital in achieving integrated urban water management. This in turn calls for a "tool kit" for urban water management planning, which would embrace the technological alternatives and fitting institutions and instruments.

Arghyam Trust, Bangalore commissioned a study to prepare such a tool kit for the use of policy makers and managers involved in urban water management programmes. The Institute for Resource Analysis and Policy (IRAP) was entrusted with this task in August 2008. Preparation of the kit took 24 months of time for the researchers and included several rounds of discussion and deliberations with Arghyam staff for finalizing the research design and methodologies and 'urban typologies'.

The study involved exhaustive review of research undertaken all over the world on various aspects of urban water management by scholars and practitioners, including but not limited to urban hydrology, management of water supply infrastructure, water resources management, water quality management (WQM), groundwater management, technical and economic instruments for water demand management, technical and economic aspects of leakage reduction, environmental and economic aspects of wastewater treatment and reuse, storm water management, capacity building for IUWM and legal and regulatory frameworks. Primary data collection for 27 cities/towns and secondary data collection for 300 cities/towns was carried out, covering all the 16 delineated typologies. Suitable sets of IUWM interventions were identified for each typology based on the understanding of how the prevailing characteristics of these typologies influence the physical, economic, institutional, financial and environmental performance of urban water utilities. Continuous interaction of the client and researchers enriched the content of the tool kit and is now ready for the use.

These are five sets of tools detailed in the tool kit. The first set will provide analytical procedures for population and urban water demand projections under different socio- economic scenarios. These tools are useful in planning decisions. Next are environmental management tools, comprising tools for choosing urban water supply augmentation strategies, wastewater treatment technologies and methods, and storm water management practices. The third set of tools deal with capacity building and organizational change issues while the fourth set of relates to community interface. Finally the last set of tools pertains to issues in good governance, covering the practical suggestions for improving the key areas of urban water governance, and the legal and policy framework for affecting implementation of urban water management interventions. I sincerely hope these tools would come handy for not only water managers of urban local bodies, but also senior policy makers, scholars and practitioners concerned with water resources, particularly urban water.

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# DEVELOPING A TOOL KIT ON INTEGRATED URBAN WATER MANAGEMENT IN DIFFERENT URBAN TYPOLOGIES OF INDIA

## 1.0 INTRODUCTION

As Tipping, Adom and Tibaijuka (2005) have acknowledged, "the 2005 IWRM target offers the potential to implement the management and policy framework essential for successful achievement of water and sanitation targets" (p.13). Likewise the UN Millennium Project Task Force on Water and Sanitation (2005) recognises the role that IWRM could play in meeting "all the Millennium Development Goals, not only the one dealing specifically with water supply and sanitation" (p.37).

However, rather surprisingly, given the importance of the urban sector to the social and economic development of most countries, little appears in the IWRM literature which explicitly considers what an IWRM approach might involve for urban centres. Moreover, few city managers or politicians have engaged with IWRM. The potential benefits of employing the IWRM concept at the intra-urban scale are at best poorly understood. IWRM is typically seen as something to do with river basins and of limited relevance as long as the city continues to be able to successfully compete to secure additional sources of water (Rees, 2006). As Molle and Berkoff (cited in Van Rooizen *et al.*, 2005) point out cities have been very effective in capturing water from agriculture using a variety of formal and informal mechanisms, such success reduces the apparent need for urban administrations to become key actors in the IWRM process.

Work on IWRM does, of course, refer to urban situations and many of the instruments that are of potential value when adopting an IWRM approach have been exemplified in an urban context. For example, there is now a wealth of material on urban demand management, pollution abatement tools, leakage control, dual supply and recycling, decentralisation and public-private partnerships. However, much of this material is instrument specific and does not explore the broader dimensions of IWRM in the urban context. Furthermore, little attention has been focused on what specific problems could arise in attempts to implement an IWRM approach in major metropolitan centres, although there are some potentially relevant lessons to be learnt from efforts to employ participatory and cooperative approaches to the solution of other urban problems (Rees, 2006). One potentially valuable set of experiences can be found in the work on sustainable cities and efforts to implement Agenda 21, a key output from the 1992 UN Conference on Environment and Development (United Nations, 1992). Agenda 21 recognises the vital role of local governments in addressing the many environmental problems encountered in developing world cities, including water-borne pollution, sanitation and vulnerability to water-related hazards (Rees, 2006).

Just as the IWRM literature has tended to neglect the urban dimension, so the now voluminous literature on urban water and sanitation provision has been largely silent on the broad role of IWRM. There are, of course, exceptions to this general statement, most obviously in countries, such as South Africa and Singapore where IWRM principles are being incorporated into the strategic planning and management of urban water services (DWAF, 2004; www.pub.gov.sg).

The urban water services literature does make reference to specific management instruments, such as demand management tools, stakeholder participation and community actions, which are potentially consistent with an IWRM approach but typically it does not consider the range of cross-sectoral actions and assessments which would be involved in the implementation of an IWRM process. For example, in the UN Habitat report on Water and Sanitation in the World's Cities, which sees improving urban services provision as part of IWRM, the discussion focuses almost exclusively on specific demand management instruments. "The aspect of IWRM with the most immediate relevance to urban water and sanitation management, however, is demand-side management (DSM)" (UN Habitat, 2003, p.193). Although DSM techniques are undoubtedly of importance and the report very usefully highlights the lessons and potential tensions arising from implementation attempts, the focus on DSM gives only a partial view of the role of IWRM in urban water management. It neglects both the interrelationships between water and other urban services and the role of the urban in the efficient and sustainable development of scarce natural and human capital resources.

## 1.1 Integrated Urban Water Management

Conventional urban water management considers water supply, wastewater and storm water as separate entities, planning, delivering and operating these services with little reference to one another (Coombes and Kuczera, 2002; Radcliff, 2003). Current urban water systems harvest large volumes of water from remote catchments and groundwater sources, deliver potable water to all urban uses and subsequently collects generated wastewater. This wastewater is removed, taken to treatment plants usually located on the fringe of the city or town, then discharged to the surrounding environment. Only 9% of this wastewater is currently reused (Radcliff, 2003). Large volumes of storm water are also generated within urban areas due to the increased imperviousness of urban catchments. The majority of this storm water flows out of the urban area, with little management of its quality and even less of it being used. As a result, the adverse impact of conventional urban water management on the water balance of these areas is substantial (Mitchell *et al.*, 1997; Mitchell et al., 2004).

In comparison, Integrated Urban Water Management takes a comprehensive approach to urban water services, viewing water supply, storm water and wastewater as components of an integrated physical system and recognizes that the physical system sits within an organisational framework and a broader natural landscape (Mitchell, 2004).

There are a wide range of tools which are employed within Integrated Urban Water Management, including, but not limited to water conservation and efficiency; water sensitive planning and design, including urban layout and landscaping; utilization of non-conventional water sources including roof runoff, storm water, grey water and wastewater; the application of fit-for-purpose principles; storm water and wastewater source control and pollution prevention; storm water flow and quality management; the use of mixtures of soft (ecological) and hard (infrastructure) technologies; and non-structural tools such as education, pricing incentives, regulations and restriction regimes (Coombes and Kuczera, 2002; Mitchell, 2004).

Integrated Urban Water Management recognizes that the whole urban region, down to the site scale, needs to be considered, as urban water systems are complex and inter-related. Changes to a system will have downstream or upstream impacts that will affect cost, sustainability or opportunities. Therefore, proposed changes to a particular aspect of the urban water system must include a comprehensive view of the other items and consider the influence on them (Coombes and Kuczera, 2002; Mitchell, 2004).

The principles of Integrated Urban Water Management can be summarised as: 1] consider all parts of the water cycle, natural and constructed, surface and sub-surface, recognizing them as an integrated system; 2] consider all requirements for water, both anthropogenic and ecological; 3) consider the local context, accounting for environmental, social, cultural and economic perspectives; 4] include all stakeholders in the process; 5] strive for sustainability, balancing environmental, social and economic needs in the short, medium and long term.

## 2.0 WHAT IS IUWM AT THE OPERATIONAL LEVEL?

There are five important considerations in urban water management: using various components of the urban water cycle viz., urban storm water, runoff from roof catchment, urban wastewater, and use of both good quality and poor quality water from surface and groundwater sources for sustainable water use; treating various components of the hydrological system as part of a single system for water resource assessments and planning, by capturing surface water-groundwater interactions, catchment-stream flow interactions, and quality as well as quantity aspects; water demand management, including inter-sectoral water allocation; cost effectiveness of the water management interventions; and use of subsidiarity principle in urban water governance and management (source: adapted from Mitchell, 2004). This would mean:

1. Use various sources of water (surface water, local groundwater, rainwater, storm water runoff) in an optimal manner for water supplies thereby reduced threat to the hydrological integrity of the water resource system, with "cost of production" of water remaining as another important consideration. Harnessing of storm water at the sites of generation reduces the chances of pollution of streams

2. Take basin as the unit for water resource assessment and planning with catchments, groundwater and stream-flows as part of the same unit

3. Leakage is reduced to minimum (both technical and administrative) in the system and the economic target leakage is achieved, thereby revenue losses to the utility are reduced to minimum.

4. All individual connections are provided with water meters with readings taken regularly.

5. The water (supply & sewerage) infrastructure is adequate enough for the poorest communities to physically access water and dispose-off the wastewater.

6. Demand for water is managed at the end user level through efficient pricing, thereby reducing the need for augmenting the supplies with high financial & environmental costs; wastewater generation is reduced, thereby reducing the capacity of sewerage systems and wastewater treatment plants, with resultant infrastructure cost saving; increased concentration of sewage improves the energy recovery rate; storm water runoff generation is minimized thereby reducing the need for large storm water collection and

disposal systems for flood control, and the chances of damage to the ecosystem health of natural water bodies.

7. The prices charged for water supply & sewerage services at the aggregate level reflect the long term marginal cost, which is referred to as marginal opportunity cost of production & supply. It would be the sum total of the cost of depletion of the resource, the cost of production and supply of water, and the environmental cost of degradation. The average prices fixed ensures full cost recovery.

8. The pricing has to be followed by institutional realignment to maximize social welfare[1].

9. Institutions are created for ensuring inter-sectoral water allocation and management, including management of water quality

10. Decentralized wastewater treatment systems wherever the geo-hydrology, climate and soils permit, and where land is available thereby reducing the need for large centralized systems

11. Wastewater from both industries and municipal uses is treated and reused or treated to effluent discharge standards and disposed off to the environment without causing negative consequence on it; or treated and put back into the water resource system on pure considerations of social and economic benefits and costs.

12. The agency has complete database of the water supply & sewerage connections in the town/city, with proper maps of the distribution and service lines.

13. The agency has adequate HR capacity for sustainable urban water management; has favourable governance systems, management structures, finances and administrative hierarchy to perform IUWM activities; appropriate legal and policy framework exist that facilitate institutional capability building to perform IUWM functions

14. The community's water use needs and priorities are taken care of. The quality standards of the supplied water match with the community's perceptions of good quality water.

15. Communities are able to do self assessment of the water demands before launching of new water supply projects so that the new systems become cost effective and the community's willingness to pay for the services also increase. Communities have the choice of tapping on multiple sources of water, on considerations of sustainability of water supplies, cost effectiveness, and environmental sustainability.

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1 According to Dinar (2000), the Incremental Block Tariffs or any pricing mechanism advocated have not shown significant gains on social welfare as the institutions implementing the policies are outdated and is unable to cater to a large section of people especially the poor.

16. Forum exists for community to oversee the quality of execution of urban water systems and its operation and maintenance.

17. Institutional mechanisms for members of the urban communities to formally lodge complaints about poor performance of urban water system exist, and redressal mechanisms are adequate and transparent.

18. Urban communities are able to effectively participate in urban water management planning; investment decision making; urban water governance; provision of some of the urban water management services; and performing some of the best practices, through appropriate local institutions and in partnership with the urban local bodies.

19. Benchmarking of performance of urban water system is done. Community's views are incorporated while choosing the indicators for performance assessment and they actually participate in monitoring & evaluation of the work, and auditing.

## 3.0 WHY WE SHOULD INVEST IN INTEGRATED URBAN WATER MANAGEMENT?

### 3.1 Economics of Investing in Water & Sanitation

According to a WHO report on cost benefit analysis (2004) achieving the MDG target in water and sanitation, by using simple technologies, from a health point of view, would lead to a global average reduction of 10% of episodes of diarrhoea. Choosing more advanced types of technologies such as provision of regulated in-house piped water would lead to massive overall health gains, but it is also the most expensive intervention. The burden of disease associated with lack of access to safe water supply, adequate sanitation and lack of hygiene is concentrated on children under five in developing countries. Accordingly, emphasis should be placed on interventions likely to yield an accelerated, affordable and sustainable health gain amongst this group. The analysis points to household water treatment and safe storage as one option of particular potential. This intervention results in high health improvements while incremental costs remain low compared to other types of interventions.

According to UN WWAP (209), achieving the water and sanitation MDG target would definitely bring economic benefits, ranging from US$3 to US$34 per US$ invested, depending on the region. Additional improvement of drinking-water quality, such as point-of use disinfection, in addition to access to improved water and sanitation would lead to a benefit ranging from US$5 to US$60 per US$ invested. According to the SIWI assessment (2005), 1.47 billion people stand to benefit if the MDG for sanitation is met. The economic benefits could be as high as USD 65 billion annually, with the greatest proportion of the benefits expected to accrue to the poorest regions in the world.

A compelling argument in support of further resource allocations to improving access to water and sanitation services is made when evaluating the health and the socio-economic benefits and the additional benefits of improving access to safe water supply and sanitation helps to support rational and informed decision-making, for resource allocation. Among the many possible and valid criteria, the ratio of economic costs and benefits of different intervention options is critically important. Also important in assessing costs versus benefits is that a ministry of health or water affairs would be unlikely to consider costs and benefits which have implications arising to other ministries, despite the importance of these costs and benefits (WHO, 2000). The implication of this is that when adopting one particular ministry perspective in evaluating cost effectiveness the true efficiency of many environmental health interventions is not measured, resulting in a cross-sectoral misallocation of resources (WHO, 2000).

## 3.2 Investments in IUWM Activities

Often questions are raised about the usefulness of IWRM concepts for poor countries in terms of social and economic returns as it calls for huge investments in human and financial capital for building new water infrastructure and creating appropriate policies and institutions (Shah et al., 2002; Shah and van Koppen, 2006). The goal of operationalising IUWM principles is to ensure sustainable water use. Then, in the context of urban areas, intuitively, the physical side of operationalising IUWM principles should include: building new water infrastructure; fixing the existing water and wastewater treatment systems; building green infrastructure; and using technologies for improving water use efficiency (source: Reed, 2006; Jønch-Clausen, 2005). The lack of sufficient empirical analysis on the social and economic return on investments in public infrastructure such as this, to an extent, prevents the urban local bodies of poor countries from taking appropriate investment decisions.

But, fortunately, such analyses are available from rich countries, though not comprehensive. A recent document prepared for the Canadian government (Alliance for water efficiency, CWWA, Polis Project on ecological governance) titled *A Stimulus Package for Sustainable Water Infrastructure Investments* pointed out that fixing existing water & wastewater treatment systems; building green infrastructure and water use efficiency plans are as important as creating new water infrastructure. Analysis in the context of Canada and United States shows that such investments in repairing & modernizing old water & wastewater infrastructure would boost economic growth and create large employment opportunities. For instance, a study by the Ottawa-based firm Informetrica Ltd. commissioned by the Federation of Canadian Municipalities shows that $1 billion in additional investment in basic public infrastructure would create 11,500 jobs, half in construction and half in other sectors. Fixing leaky pipes and updating existing water infrastructure could provide at least twenty years of major construction employment.

In a recent paper *Transforming Water: Water Efficiency as Stimulus and Long-term Investment*, the Alliance for Water Efficiency calculated that a $10 billion investment in water efficiency in the U.S. would boost GDP by $13 to $15 billion and create between 150,000 and 220,000 jobs in over 20 different economic sectors. Investment in water efficiency programs can be rapidly deployed allowing the federal government to hit the ground running while it mobilizes resources for larger public works projects. The Alliance for Water Efficiency has identified a range of demonstrated approaches for quickly deploying efficiency programs in the field, initiated in time periods of 90 days or less.

The greatest impact of investment in sustainable water infrastructure would occur in low income areas, where water distribution infrastructure is frequently inadequate and public health risks are greatest. Investment in these areas would create green employment opportunities where unemployment rates are highest.

Creating a policy and budgetary framework that promotes a 21st century approach to sustainable water infrastructure will cultivate innovative green solutions and foster Canadian innovation in the burgeoning global water-tech industry. This is an industry that is set to grow rapidly as the challenges of water scarcity and clean drinking water become more pressing nationally and globally.

The business community has identified the potential value of innovative water solutions such as those applied by Pure Technologies, a company that develops technologies for inspection, monitoring and management of water infrastructure. A recent report from New York based Lux Research, called *Water Cultivation: The Path to Profit in Meeting Water Needs*, states that revenues of the world's water-related businesses will rise from $522 billion in 2007 to nearly $1 trillion by 2020 and predicts that a world faced by water shortages will need a new "water cultivation" approach characterized by efficiency, reuse and source diversification.

## 3.3 Objectives of the Research and the Methodology

The goal and objectives of the research are provided in the proposal. The key research questions are also discussed in the proposal. The broad methodology followed in the research is eclectic. It involves: identifying the factors leading to good performance of urban water systems. This is done by: 1] field based research and analysis of primary data to assess and compare the performance of urban water systems of selected utilities; 2] analysis of secondary data collected by reputed and established research organizations, central government agencies and multi-lateral donor agencies on urban water systems of selected utilities and comparative analysis of their performance; 3] synthesizing the findings of the hard-core scientific research undertaken internationally on physical, social and economic aspects of urban water management and which are available in various international journals, published research and technical reports; and, 4] discussions with various technical experts on urban water management. The specific methodology to be followed for addressing the research questions are discussed in the proposal.

# 4.0 IUWM FRAMEWORKS

## 4.1 Generic Operational Framework for IUWM

The schematic diagram shown in Figure 1 has three important components. First is the water use system. The second is the water supply, storm water collection, and wastewater treatment system. The third is the water resource system, which includes water from desalination and imported water. These systems are interlinked. How much water is drawn from the water resource system depends on the demand for water in the water use system, and the network losses. The amount of wastewater generated demand on the water use.

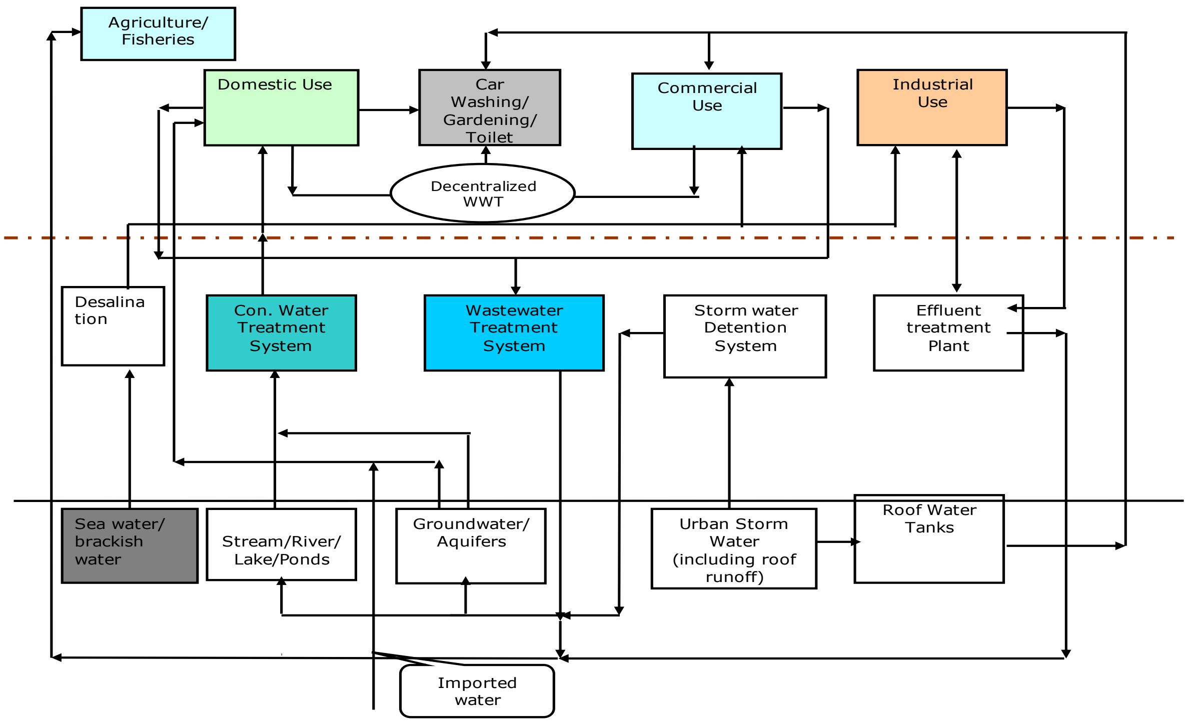
As indicated in the schematic diagram, treated water from the conventional water treatment system, which is of high quality, is used to meet the water demands for domestic purpose and municipal uses. Relatively poor quality water is used for gardening, vehicle washing and toilets. The wastewater generated is either treated locally or goes to a centralized treatment system. The treated water either joins the streams or groundwater or is available for reuse in agriculture. The storm water generated in the urban area including that from roof catchments is also collected, treated and can augment the water resources for use in urban areas.

As the box on the top right hand side indicate, the water use is a function of several complex physical, socio-economic and institutional and policy factors, viz., income level, water pricing structure and prices, supply restrictions, climate, seasons and culture, pollution tax and pollution control norms, subsidies for water conservation technologies, groundwater regulation and tax, presence of social institutions and organizations. The demand for water reduces with increase in price, and less elastic to price changes under hot and arid climates and also when income levels are high.

On the other hand, the wastewater, if treated and recycled or reused, can reduce the effective water supply requirement in the urban areas. For instance, the domestic wastewater can be treated and reused for gardening, car washing and toilets. If not treated, it can deteriorate the quality of water in the natural systems and ecosystem health. The nature of raw water treatment, water supply and wastewater treatment systems depend on water quality standards applicable to the urban area, climate, hydrology and quality of water available from the natural system, technologies available for wastewater treatment, financial health of the water utility, economics of various water and wastewater treatment options and land availability. To elaborate, when stringent water quality standards are strictly enforced by the enforcing agencies (say the Pollution Control Board), the incentive to set up wastewater treatment systems that treat water to very high standards would be high among the water users like the municipality and industries. Similarly, large-scale wastewater treatment systems cannot be employed in congested urban centres, with very high land value.

The availability of water from the water resource system for water supplies depends on hydrology, geo-hydrology of the basin/aquifer in which the region/basin, natural water quality, urban land use and land cover, type of housing stocks and topography. In addition to the conventional sources of water (such as river/streams, lakes/ponds and groundwater), urban areas can augment their water supplies through rainwater harvesting. But, the amount depends on the rainfall (hydrology) and the total roof area and roof characteristics. The urban storm water, if collected treated in detention systems, can be used to augment the lakes, or aquifers.

Figure 1: Generic Framework for Integrated Urban Water Management (IRAP (2010) Developing a Tool Kit on Integrated Urban Water Management in Different Urban Typologies of India)




**Income Levels**
**Water pricing**
**Supply restrictions Culture**
**Pollution tax/Pollution Control norms**
**Subsidies for water conservation technologies**
**Groundwater regulation**
**Groundwater abstraction tax**
**Water availability**
**Social institutions/organizations**

**Water quality standards**
**Climate**
**Hydrology**
**Water quality**
**Technology availability for W/WW treatment**
**Finance**
**Economics**
**Land availability**
**Management Capacity**

**Hydrology**
**Geo-hydrology**
**Water quality**
**Land use & land cover**
**Type of housing stocks**
**Topography**

## 4.2 Construction of Urban Typologies

The type of water management interventions, which are sustainable for an urban area, would depend on a wide range of physical, socio-economic, cultural and institutional factors. Physical factors such as the hydrological regime, the geological environment, climate and topography will have a great bearing on the water supply option, which is sustainable for an urban area from physical and economic points of view. For instance, hydrological opportunity for roof water harvesting purely depends on the magnitude of annual rainfall, and the cost per unit volume of the harvested water would depend on the pattern of rainfall. Similarly, the rainfall and topography would greatly influence the type of storm water drainage system which is required as it would influence the peak runoff from the urban storms, and the surface drainage possibilities. Geo-hydrology, rainfall and the climate together would greatly influence the degree of vulnerability of aquifers to pollution from on-site sanitation and effluent disposal. Therefore, they would also determine the potential of using land-based treatment processes for wastewater. In the same way, the climatic factors (temperature, sunshine and wind speed), and altitude would influence on the effectiveness of bio-chemical treatment processes.

Overall water situation (whether water is naturally scarce or abundant), which is determined by a range of physical factors, can influence not only the cost of production & supply of water, but also the viability of water metering & pricing. The ways in which these factors influence the various physical options for urban water management are illustrated in the tool descriptions for Tools 3-9.

On the socio-economic front, characteristic like the level of urbanization would have a great bearing not only on the feasibility of demand management options such as metering and volumetric pricing, but also on the economic viability of some of the wastewater treatment options. As regards the first, high level of urbanization would increase the social affordability of payment for water supply services. As regards the second, the price of land also would change with the level of urbanization, thereby affecting the viability of certain wastewater treatment options. Besides these, land availability, which is an inverse function of urban population density, is a crucial factor determining the type of wastewater treatment system viable for an urban area. The size of the urban area (whether big or small) will determine the viability of some of the water supply options, determined on the basis of some of the physical factors, for water supply for an area. Here again, the manner in which these factors influence the decisions on demand management options are illustrated in the tool descriptions for Tools 10-14.

But, India is a country with a lot of spatial heterogeneity in the physical, socio-economic and cultural conditions. Particularly, annual rainfalls, annual evaporation (determined by temperature, relative humidity and wind speed), geology, and topography vary spatially and these variations show a pattern. There are regions with high rainfall and humidity. Also, there are regions with extremely low rainfall and hyper-aridity. While the country has a total of 5,000 plus towns/cities, all sizes are found, starting from large metros, large cities and small towns. There are small towns which are highly urbanized. At the same time, there are large cities which have up to 50% population living in slums. Again, within that, the level of urbanization can change from town to town.

The urban administration can be Town Municipal Council, or Municipality or Municipal Corporation or Metros, which will have a great bearing on the technological option which can be opted for to supply water, and institutional models which need to be pursued. Now, there are a large number of permutations and combinations possible vis-à-vis the physical environment, socio-economic setting and the type of administration. It is difficult to develop a tool kit for each and every situation, which can be encountered. Therefore, it is important to identify the dominant typologies emerging from a combination of characteristics, be it physical, or socio-economic or administrative, and design tools for various components of integrated urban water management system for each one of them. A typology here is a geographical domain, which are similar vis-à-vis certain characteristics. For instance, places with low rainfall and high aridity cover large areas in the country, but those with low rainfall and high humidity is uncommon. Also, basalt formations are either in the plateau region or in the plains, but are not found in hilly terrain.

The tool kit is developed for dominant typologies that use physical characteristics, viz., rainfall, topography, geology and climate of the urban area. The reason is there is general spatial trend in most of these characteristics. While designing the tools, the unique situations vis-à-vis the socio-economic features and administrative types of the urban areas are incorporated separately within each typology, on a case to case basis, depending on whether that particular characteristic matters or not for the tool in question. The major reason for doing this is that no general spatial trend in many of the socio-economic characteristic is seen unlike in the case of physical characteristics. For instance, highly urbanized large cities are found throughout India, except in the north east. Cities with high and low population densities are found everywhere. In order to identify the dominant typologies, we have superimposed the India maps, each one showing the variations in one physical characteristic, on the map which shows different types of urban areas. Using the superimposition of the thematic layers, we have identified 16 dominant typologies. The characteristics of these 16 typologies are described in Section 4.4.

## 4.3 Over-arching Practices in IUWM

- In high rainfall hilly and mountainous, roof top rainwater harvesting should be part of the mainstream water supply system

- In urban centres falling in low to medium rainfall areas, RWHS would be suitable for only large bungalows. But, provision of subsidies for the same should be subject to metering and volumetric pricing of supplies from the public utility. The level of subsidy should be equal to the unit cost of production of the amount of water that can be harnessed by the system.

- In order to encourage all bungalow dwellers to adopt RWHS in (low and medium rainfall) water scarce regions, it is important that incremental block rates for pricing of urban water are adopted. In this case, the pricing for levels of use higher than the basic needs should be fixed in such a way that it is higher than the unit cost of production of water through roof water tanks. The idea of incremental block rate is that the dwellers do not use municipal water for such needs as car washing, and gardening..

- In flood prone areas (cities located on the banks of flood-prone rivers in the east, and also in south Gujarat), flood management would be critical to achieving sustainable urban water supplies, and sanitation that ensure basic survival, community health and environmental management.

- In areas prone to water-logging (shallow water table areas), contamination of groundwater from leaching types toilet should be utmost concern.

- In high rainfall, mountainous areas, roof water would be an important resource and source for urban water supplies from the point of view of augmenting the water supplies and also making it cost effective.

- In low-lying cities that receive very high rainfall that cause flash floods, collection of roof runoff in tanks would help reduce the intensity of floods, thereby reducing the capacity requirements of storm water drainage systems.

- In semi arid and arid areas, the urban storm water can be detained in detention ponds instead of allowing it to be mixed with sewage and effluent; this can be used to recharge groundwater (if water table is deep enough) using the method of aquifer storage/recovery systems. Urban wetlands can be used for detention like in Hyderabad and many cities of the south.

- In sub-humid and humid areas, urban storm water can be stored in decentralized detention ponds for sedimentation, and then discharged into natural drainage systems. This can reduce the capacity requirements of storm water drainage systems, and prevent urban floods.

- In large urban areas falling under low-medium rainfalls, with larger proportion of geographical area covered by "built up area", rain gardens should be promoted. Remote sensing and GIS would be a good tool for decision making in this regard.

- Wastewater treatment and reuse: land availability and land prices would be important considerations in choosing WWT technologies.

- Domestic wastewater has to be separated from industrial effluent to reduce the treatment costs. This would make treatments easy and feasible. Also, sewage has to be separated from storm water

- Decentralized treatment of the domestic wastewater and its reuse in the same localities would reduce the infrastructure and energy requirements for collection and disposal. It would also reduce the municipal water demand. For example: use of grey water for irrigating gardens and toilet flushing; this would be viable for posh areas. Black water will have to be taken out to centralized treatment systems for removal of BOD, COD and pathogens.

- Anaerobic treatment of wastewater would remove the organic matter and suspended solids; help generate energy from biogas (biogas); also, it is advantageous from the point of view of reuse of the treated water for irrigation and pisciculture as the heavy metals would be removed. For aerobic treatment, very little land is needed, but energy intensive and generates a lot of sludge

- Growing duckweed is useful for removing the nutrients (nitrogen and phosphorous) and heavy metals from wastewater; the same biomass produced from the nutrient uptake can be used to grow fish in other ponds provided it does not contain heavy metal residues. This is suitable for sub-humid and humid environments.

- Industrial wastewater could be treated using bioremediation. This can be used in towns, where land is available in plenty.

- In humid and cold areas, aerobic treatment has to be practiced[2]. Since irrigation demand would be less in these areas, water has to be diverted for pisciculture. Some nutrients can be removed through bio-remediation. Pathogen would be a problem while using this treated water for irrigation.

- In highly arid and semi arid areas, waste stabilization ponds would be ideal. But, land availability is a key factor as amount of land required for WSP is very large. The soil aquifer treatment would work in areas with deep water table conditions and soil is permeable.

- In urban areas with very few polluting units which follow similar processes and produce same type of effluents, stringently following pollution control norms would be a viable strategy.

- In urban areas with scattered populations (with low population density) and also in centres where population size is very large, a part of the wastewater (*grey* water) should be first treated in decentralized treatment systems, and only the remaining (*black* water) should only be taken to centralized systems.

- Decentralized sanitation systems (leach type, and septic tanks) can be encouraged only if groundwater table is deep, or is of poor quality and not used for human consumption.

- Effluent from septic tank from housing stocks and commercial establishments could be used in reed beds/constructed wetlands for further improvements in area where sewerage system connection is not available, as constructed wetland is suitable for low concentration of loading.

- In small towns (towns and municipalities), since groundwater contribution to water supplies is high, the effort should be to augment the groundwater reserves, by levying prices (taxes) that cover resource cost, production cost and cost of environmental damage; and using it for recharge projects like SAT.

- In larger towns and cities, the users of private well water, who are not connected to the utility services, shall be levied charges that include only resource cost & environmental damage costs. At the same time, the "charges" for those connected to the utility, but still use private wells, should be kept at such levels that their total cost of water supply is comparable or higher than what the utility charges. The idea is to make the opportunity cost of deferring metering and payments to the utility high.

- Actions of RBOs should be coordinated with those of the urban water utilities, as either of their actions would affect each others' performance. The users of private wells should get the permits for groundwater withdrawal from the UWUs, which, in turn, have to get the

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2 Aerobic treatment (like ASP) is energy intensive for providing oxygen through mechanical means. It also generates a lot of sludge. Anaerobic treatment requires more land. No mechanical energy is required. But, it is time consuming. Sludge deposition is less as compared to aerobic treatment.

water rights, from the RBO. But, what the utility charges would be higher than what the RBO levies from the utility.

- RBOs's wing should also carry out pollution treatment, and the utility has to pay the environmental cost component of the water charges to the RBO.

- The agency doing regulatory functions of Water Quality Management and the agency which carries out pollution control measures should be separate.

- The pricing of water and sewerage should reflect the increasing long-run marginal costs of water supply and its disposal, specifically addressing the costs of environmental damage in production and consumption, and the opportunity costs of depletion. This is referred to as marginal opportunity cost production (MOCP).

    This can be defined as: MOC = MDC + MEC =MUC

- The cost of using/depleting water would vary from region to region, but would be highest in the most water-scarce regions. This would however, be determined by the alternatives uses of water that exist in the region under consideration.

- Decision to do metering should be based on cost-benefit analysis. Water metering and volumetric pricing should receive priority in urban areas that have high percentage of UFW, and in areas where physical scarcity of water resources is of higher degree.

- To make urban water affordable to the poor, either subsidies should be paid by the government through the distribution of water coupons, or incremental block rates with very low rates for basic level of consumption could be introduced.

- Leakage prevention in the water supply system would be a major area for IUWM interventions, and must receive high priority in urban centres that have populations scattered over large geographical areas, and also those having undulating terrains which increase the leak.

## 4.4 IUWM Framework for Dominant Typologies

Using the generic IUWM framework, the over-arching principles & practices in IUWM, and the specific characteristics of different typologies, alterations in the generic IUWM operational framework to fit into different typologies are identified. They are prescribed for each dominant typology below.

### 1) **Alluvial-Plain-Low Rainfall-High Evaporation** (A1-P1-H3-E3)

Water source: Groundwater pumping for small towns and municipalities; groundwater and imported surface water for corporations and metros; excess imported surface water to be used for recharge

Wastewater treatment: waste stabilization ponds (WSP) for small towns and municipalities and treated water to be used for irrigation purpose; SAT in river bed aquifers for large municipalities/corporations to be used for recharging the aquifers; decentralized WWT systems (reed bed; WSP etc.) for reuse in gardening; toilet and car washing; then centralized treatment for excess water using membrane (if water is imported) for reuse

Storm water management: collection and storage in detention ponds and discharge into streams for gravity recharging

### 2) **Alluvial-Plain- Moderate to High Rainfall-High Evaporation** (A1-P1-H5-E3)

Water source: groundwater as source of water supply for small towns, municipalities (with % contribution from groundwater decreasing with population size); groundwater pumping by individual users in large municipalities to be restricted; and in metros to be based on permits; imported surface water in large corporations.

Wastewater treatment: waste stabilization ponds (WSP) for small towns and municipalities and treated water to be used for irrigation purpose; SAT in river bed aquifers for large municipalities/corporations to be used for recharging the aquifers; decentralized WWT systems (reed bed; WSP etc.) for reuse in gardening; toilet and car washing; then centralized treatment for excess water using membrane (if water is imported) for reuse; treated wastewater for irrigated agriculture in peri urban areas

Stormwater management: storm water to be collected in detention ponds (local) and discharged into streams for gravity recharging

### 3) & 4) **Extensive Alluvium-Plains-Moderate to High/Very High Rainfall- Low Evaporation** (A1-P1-H5/H7-E2):

Water source: river lifting and groundwater as source of water supply for small towns, municipalities (with % contribution from groundwater increasing with population size); Groundwater pumping by individual users in small towns and municipalities to be unrestricted; and in metros to be based on permits

Wastewater treatment: Centralized wastewater treatment using ASP; treated wastewater to ponds for nutrient removal using DWT; later on for fish production

Stormwater management: storm water to be collected in detention ponds (local) and disposed off into rivers after cooling; in very high rainfall areas, rain gardens can be constructed for runoff reduction. In flood prone areas of both typologies, storm water from roof tops can be collected in roof water tanks and the excess can be released into the storm water drains.

### 5) **Alluvium/Sandstone-Plain-Moderate Rain-High Evaporation** (A2-P1-H4-E3)

Water source: groundwater for towns; groundwater + imported surface water for large municipalities and corporations

Wastewater treatment: decentralized waste treatment systems such as septic tanks; centralized WWT systems such as WSP; treated water to be used for irrigation

Storm water management: collection, storage into detention ponds and discharge into streams after sedimentation & cooling

**6) Alluvium/Sandstone-Plain-High Rainfall-Low Evaporation** (A2-P1-H6-E2)

Water source: river water/tank/well-managed lake water for towns; river water + groundwater for large municipalities

Wastewater treatment: activated sludge process; treated water to be used for fisheries

Stormwater collection and safe disposal in streams after pond detention

**7) Alluvium-Hill-High Rainfall-Low Evaporation** (A2-P3-H6-E2)

Water source: well-managed lake water +groundwater for the towns in the area

Wastewater treatment: activated sludge process; treated water to be used for fisheries

Wastewater treatment: anaerobic treatment using waste stabilization pond

Storm water management; no special actions will be needed, except collection & conveyance of storm water through UGDs, as the surface drainage will be extremely good in the hills

**8) Thar Desert** (A2-P4-H1-E3)

Source of water supply: well-managed local tank/pond as water source for small towns; imported surface water for large towns/cities (Jodhpur for instance)

Decentralized treatment system for black water (septic tank) for scattered clusters; waste stabilization pond for domestic wastewater treatment; treated sewage to be diverted for irrigation; membrane technology for treatment and reuse in case of imported water

Stormwater management: Storm water collection and storage in natural ponds/tanks after detention as aquifers are saline

**9) Crystalline Rock-Plain-Moderate to High rainfall-Low Evaporation** (A3-P1-H5-E2)

Source of water: well managed tanks/ponds for small towns; imported surface water from nearly or distant reservoirs for large cities

Wastewater treatment: activated sludge process, treated wastewater to be used for fish production

Storm water management: runoff reduction measures in large cities and towns with large built up area, and collection of excess runoff in detention ponds and then surface storage; just collection, detention and disposal of storm water in towns in small built up area

**10) Crystalline Rock-Plain-High Rainfall-Low Evaporation** (A3-P1-H6-E2)

River/lake water for small towns/municipalities; river/lake water + groundwater for corporations; as water source; river/lake water + imported surface water in metros

Wastewater treatment: ASP for wastewater treatment; disposal into tanks/lakes of treated wastewater for fish production

Storm water: to be collected in local detention tanks; and to be diverted into streams/tanks/lakes

### 11) & 13) Crystalline Rocks/Basalt-Plain/Plateau-Low/ Moderate Rainfall-High Evaporation (A3/A4-P1/P2-H4-E3)

Water source for utility: water from well-managed lakes/tanks for small towns; groundwater pumping & surface water from lake/tanks for small towns & municipalities; imported surface water for corporations, with small percentage of well water; and only imported surface water for metros (well managed lakes to be used for recreation; fisheries in urban centres).

Wastewater treatment: centralized WSP for WWT in small towns and municipalities and diversion for irrigation; decentralized treatment systems for domestic wastewater (reed bed technology; WSP) to be used back in gardening; car washing & toilet use in large cities; the excess wastewater to be taken to centralized WWT systems and disposal of treated water in lakes/tank

Storm water management: Runoff reduction measures other than RWHS & RG; excess storm water collection, detention ponds, and surface storage

### 12) Crystalline Rocks-Mountainous region-Very High Rainfall-Low Evaporation (A3-P3-H7-E2)

Water source: Roof water harvesting tanks + river lifting

Centralized wastewater treatment for wastewater using Activated Sludge Process (as anaerobic systems won't work due to poor sunlight and low temperature)

Nutrient removal from wastewater using duck weed in natural lakes; use of the treated wastewater for fisheries

Storm water management: collection and disposal into streams; no need for detention ponds

### 14) Basalt-Hills-Moderate Rainfall-High Evaporation (A4-P3-H5-E3) (T, M)

Water source for utility: water from well-managed lakes/tanks for small towns with some amount of lifting; restricted use of the limited groundwater available in the rocky & hilly terrain

Wastewater treatment: waste Stabilization ponds, treated water to be used for irrigated agriculture

Stormwater management: Collection and conveyance of storm water through UGDs, and drainage of water from the town will be through gravity

### 15) **Coastal Alluvial-Plain-High Rainfall-Low Evaporation** (A5-P1-H7-E2)

Water sources: Water from tanks/ponds and river bed for small towns and municipalities; groundwater pumping + tank/ponds/river bed for corporations; and imported surface water for large metros; Roof water collection systems for scattered populations

Wastewater treatment: Activated sludge process; and disposal of treated wastewater into the ponds/tanks for fish production for towns, municipality & corporation

Membrane technology for higher level of treatment and reuse for domestic purpose in metros; sludge to be disposed off into the sea/ocean

Storm water management: collection in detention ponds; and disposal in to streams after sedimentation and cooling; recharge into aquifers in cities with large built up area

### 16) **Coastal-Plain-Low Rainfall-High Evaporation** (A5-P1-H3-E3)

Water source: Surface water + groundwater for small towns; surface water +groundwater & desalination in municipalities and corporations; and imported surface water +desalination of saline groundwater or seawater in metros

Wastewater treatment: membrane technology for large cities (metros); and treated wastewater to be used for domestic water supplies other than drinking; SAT/waste stabilization pond for treatment of wastewater for small towns and municipalities; treated wastewater to be diverted for irrigation in the peri-urban areas

Rain garden for collection and simultaneous recharge of storm water for corporation and metros (with large built up area)

## 5.0 URBAN WATER DEMAND PROJECTIONS

Urban water demand is a function of population and per capita water demand. The per capita demand (here we refer to the normative water demand) varies with income levels and climate. Rising income can lead to increased water demand as water needs for environmental services such as gardening, tree plantation, and environmental flows in rivers/streams increases (Rosegrant et al., 1999). Water demands are higher in hot and arid, and hot & humid climates as compared to cold & humid climates. The growth in per capita water demand is also a function of how the population is growing (WRI, 1995). The reason is this. Higher growth in urban population is likely to trigger growth in demand rate itself, which is owing to greater need for water for environmental sanitation. Larger cities would require greater amount of water for watering tree plantation etc. Hence, there are two sets of challenges in urban water demand projections: doing correct projections of future population growth rate; doing correct projections of per capita water demand. We would discuss the determinants for urban water demand projections in the subsequent sections.

## 5.1 Population Projections

### 5.1.1 Conceptual Issues in Population Projections

There are conceptual issues in urban population projections owing to the mismatch between the city administrative boundary and the territory of the urban area. When the administrative boundaries of cities remain fixed for long periods of time, they are likely to misrepresent the actual growth of a city in both territorial and population terms. When administrative boundaries change with relative frequency, one can assume that they are reflecting the actual territorial expansion of the urban area linked to the functioning of the city, with habitations at urban levels of population density. Two metros where such expansions have happened in the very recent past are Bangalore and Ahmedabad. For a given city, if the population data are available for both "city proper" and metropolitan area, the second one should be preferred because they are expected to better represent the territory associated with the urban agglomeration than the data based on administrative boundaries.

For any given city, effort should be made to ensure that the time series data of population conforms to the same definition over time. Adjustments have to be made whenever necessary to achieve internal consistency. Often, the changes involved demand that the criterion for assessing the population of a city is changed. That is the case when data on a city in terms of the urban agglomeration are available for only one or two points in time and there is a longer and more consistent series of data on the population of the "city proper". In those circumstances, the data on the city proper, based on administrative boundaries, are used instead of those on the urban agglomeration since a sufficiently long time series based on the latter concept is normally not possible to reconstruct from the data available. When such reconstruction is possible, it is undertaken.

### 5.1.2 Factors influencing Urban Population Growth

#### Female Literacy

Here, we discuss the factors that seem to influence the way population in urban areas would grow in future. There are several uncertainties in forecasting urban populations due to several factors affecting urban population growth in addition to TFR. Among the different sources of uncertainty, uncertain changes in the structure of heterogeneous populations have received little attention so far, although they can have significant impacts (Lutz and Scherbov, 2004). This is the first attempt to capture the structural change with respect to education, a greatest measurable source of fertility heterogeneity in Asia. Their study focused on the effect of changes in the educational composition of the population on the overall fertility of the population in the presence of strong fertility differentials by education. With data from India, Lutz and Scherbov (2004) showed that alternative paths of future female enrolment in education would result in significantly different total fertility rates (TFR) for the country over the coming decades, even assuming identical fertility trends within each education group. These results from multi-state population projections by education are then translated into a fully probabilistic population projection for India in which the results of alternative education scenarios are assumed to expand the uncertainty range of the future TFR in the total population.

Therefore, it is very important to know how the female enrolment in education is changing over time in cities. This also means that towns/cities with structural changes in population with respect to female education will have different population growth paths.

## Structure of Urbanisation and Fragmentation of Space within Cities

The dynamics of urban development in India can be analysed by looking at the interdependence of the level and pace of urbanisation in relation to indicators of economic development, taking the 25 states in the country as the units of observation. The correlation of per capita income, industrialisation, infrastructure, etc. with level of urbanisation at different points of time in the post-independence period is strongly positive (Kundu, 1994). This is understandable. The growth process during the colonial period in India was marked by spatial inequality wherein a few states that had large cities, access to sea routes, etc. attracted much of the industry and infrastructure capital. Urban growth after independence, however, shows a weak but negative relationship with economic development. This is because the pace of RU migration and urbanisation are high in many of the backward states and regions that seem to be stuck in the vicious circle of poverty. It is, therefore, difficult to view the urban processes as healthy, leading to balanced regional development in India since it is often linked to push factor out-migration from rural areas.

The distribution of population in different size class of settlements has become highly skewed over the years. In urban population, the share of Class I towns or cities, with population size of 100,000 or more, has gone up significantly from 26 per cent in 1901 to 65 per cent in 1991. The percentage share of class IV, V and VI towns, with less than 20,000 people, on the other hand, has gone down drastically from 47 to 10 only. This is largely due to the fact that the towns in lower categories have grown in size owing to population growth and entered the next higher category. Unfortunately, however, there has not been a corresponding increase in the number of urban centres, especially at the lower levels, through transformation of rural settlements. During the 90-year period from 1901 to 1991, the number of urban centres doubled while urban population has increased eight-fold. Indeed, the absence of a process of graduation of large-sized villages into towns, through growth of industrial and tertiary activities, remains the major problem in India's urbanisation.

The second reason for the urban hierarchy becoming top heavy is that the larger urban centres have experienced faster demographic growth as compared to smaller settlements. The class I cities, for example, registered an average annual growth rate of 3.0 per cent during 1981-91, which is higher than that of lower order towns. More important, the class I cities exhibit a lower disparity in their growth rates, measured through coefficient of variation, compared to those in other size classes. Scholars have argued that the former experience relatively high and stable demographic growth because they are linked to the national and sometimes international market (Nagaraj 1987, Kundu, 1983 and Bhalla and Kundu, 1982). In the smaller towns that are mostly rooted in their regional economy, however, population growth tends to be low and fluctuating over time and space. This provides a basis for the proposition that in India, there exists a dual urban structure wherein the larger cities are integrated with the higher order system and are part of a growth dynamics, which, by and large, is absent in the smaller towns.

The demographic growth in urban centres in different size categories across the states shows a significant imbalance, wherein in the less developed states, the small and medium towns with population below 50,000 have grown at a relatively rapid pace, similar to or even higher than that of the class I cities. In the developed states, however, these towns exhibit a lower growth.

Detailed empirical analysis reveals that the growth of small and medium towns in the less developed states is not backed up by manufacturing and commercial activities or infrastructure facilities (Kundu, 1994). More than a quarter of the workers in these towns is engaged in agriculture that can hardly yield any revenue to the civic authority. They have a small proportion of workers engaged in manufacturing about half that of class I cities, and this share has declined significantly in recent years. Rural poverty, stagnant agriculture, absence of sector diversification, etc., emerge therefore, as possible explanations for the imbalance.

Importantly, the recent changes introduced in the system of urban governance and planning have serious implications for the pattern of urban growth. During the 1950s and 1960s, physical planning controls on location of economic activities and urban land-use, imposed through Master Plans, etc., had put some kind of ceiling on the absorptive capacity of large cities. These, to an extent, had constrained RU migration. Presently, however, a strong lobby is emerging, particularly in these cities, pleading to disband all zoning restrictions, building laws and bye-laws, and to make them relatively independent of state and central level controls. It is stipulated that decisions regarding location of industries, change in land-use, etc. should be taken expeditiously at the local level. The decentralisation of responsibilities for development planning, which the 74$^{th}$ Constitutional Amendment sought to introduce, is helping this lobby through empowerment of local governments in large cities that have relatively strong economic bases. As a consequence, a few of these cities will be able to attract both capital and labour and record a high population growth. The small and medium towns, on the other hand, are unlikely to benefit from this changed policy regime.

Many of the state and city governments are trying hard to create a few "global centres of the future", wherein they can attract local and international investment. Land is being provided at preferred sites to upcoming industrial and commercial houses both through government intervention and by activating the land market. Steps are being taken to facilitate changes in land-use pattern through simplification of legal and administrative procedures and by enabling the market to push "low valued" activities out of the city core. The low income and slum colonies are the obvious candidates for relocation in city peripheries. The shift is being carried out by the state or local governments, often directly through eviction of slum dwellers, hawkers, pavement dwellers etc. Sometimes, it is done indirectly and discreetly through slum improvement schemes, "rehabilitating" them outside the city limits. Unfortunately, that has been done mostly without making any provision for alternative employment opportunities for the displaced workers. This can only lead to high disparity in population density and quality of life, and segmentation of the cities into rich and poor colonies.

These prospective global cities are currently facing two problems in attracting foreign and Indian business houses and industrialists. One is scarcity of land within the central city and other prime locations; the second is deficiency of infrastructure. An ingenious method has been worked out by some of the local governments to solve this twin problem. The agencies like World Bank, USAID, etc. have recommended that the Floor Space Index (FSI) in the central areas of the city should be increased so that multi-storied structures can come up, providing space for business houses, commercial activities and high-income residential units. The policy of giving permission for vertical growth at a high price or selling of extra FSI in central and business districts has been welcomed by many local bodies as an easy way of generating resources for infrastructure development. There is further incentive to this since sanctioning of loans by the international agencies is often contingent on the acceptance of a higher FSI in the central city by the local authorities. This would lead to the creation of a few high-density business and high-income residential districts, pushing out households that could not afford the costs.

A large number of the industrial units in the post liberalisation phase have come up in the villages and small towns around the big cities. The reasons for moving out of the large cities are easy availability of land, access to unorganised labour market and lesser awareness or less stringent implementation of environmental regulations. The poor are able to find shelter in the "degenerated periphery", get jobs in the industries located therein or commute to the central city for work (Kundu, 1989). The entrepreneurs, engineers, executives, etc., associated with modern industries and business, however, reside within the central city and travel to the periphery through rapid transport corridors. This process of segmentation, manifested in different variants in different cities, would bring the large part of rural migrants into the peripheral zones.

Further, a clause in the 74th Constitutional Amendment Act would make it possible to provide differential levels of amenities in large cities, at the level of ward committees, based on willingness of the users to pay. This is likely to institutionalise disparity in the availability of civic amenities. This process, operated through the market and backed up by governmental programmes, is likely to affect the pattern of population absorption in the cities. Elitist preference for low density and clean micro-environment would ensure no illegal encroachment and only selective new construction in core areas and high-income colonies. Consequently, most of the incremental population would be absorbed in slums, low lying and other marginal lands and city peripheries. A switch from a centralised to a decentralised system of decision-making may, thus, result in high disparity in demographic growth within and around the cities and reinforce the process of segmentation into rich and poor colonies.

The following can be concluded from this: the larger cities are likely to grow much faster in the future, and would account for a larger share of total urban population; the smaller towns would experience lower growth rate, and their numbers is likely to reduce over time, with not many big villages transforming into towns. In less developed states (UP, Bihar, Orissa, MP and Jharkhand), the poor female literacy rates in smaller urban centres would be a major determining factor for high urban population growth. The large cities are likely to experience large-scale emergence of slums or degenerated areas in their peripheries, with large concentration of population.

## 5.2 Factors Influencing Per Capita Urban Water Demands

### 5.2.1 Per Capita Economic Water Demand as a Function of Price

Economic demand for water is the volume of water for which the consumers are willing to pay the price decided by the market. Since the economic and social values that can be generated from the use of water will vary inversely with higher levels of use for a given consumer, theoretically, the demand for water would reduce with increasing prices if the economic condition of the consumer, which in fact influences his/her ability to pay for water, remains the same. We need to examine how this happens.

Now for essentially all uses, water consumption can be varied substantially by small changes in methods of use. Water is usually one input into a socio-economic and biological production process. There are opportunities for changes in input proportions in response to movements in relative prices. Moreover, part of demand is waste, i.e., a failure to fix leaking pipes, or to turn off taps after use. The price of water will strongly influences these so-called water losses, as the consumers will try to maximize the surplus value generated from its use. An aspect of "waste", which is not widely recognized, is that if water is very inexpensive, "wasting" water is perfectly rational. If water is inexpensive, simply because it is plentiful and its delivery costs are very low, then "wasting" water is inefficient only if creates a significant external diseconomy.

This applies to water utilities as well. A frequently used indicator of the efficiency of a water utility is its proportion of “unaccounted for water” (UFW). One source of UFW is a leaky distribution system. Repairing leaks is worthwhile only if the value of the water saved justifies the investment in new pipes. It may not be economically viable, if plentiful, high-quality water is available nearby.

If price elasticity of water demand exists, a mistake in pricing can have large consequences for water use. Prices that are too low create a demand to expand water delivery beyond the efficient point. Under-pricing of water can be very expensive to the society as it would result in massive, uneconomic expansion of the water delivery system. Alternatively, if water prices must cover all costs and if costs are high due to inefficient or corrupt management, much economically warranted water usage can be cut off, and a small improvement in the efficiency of the operation of the water utility can yield large economic benefits.

Water pricing fails to generate desired social benefits when the consumers do not attach enough value to water because of information imperfections. Some users may lack understanding of the relationship between water quality and health. Others may understand these relationships in principle, but they cannot effortlessly[3] observe aspects of poor water quality such as the presence of microorganisms or trace chemicals that are health hazards. Here, consumers may respond to higher prices for piped water by consuming too much low-quality water from contaminated alternative sources. This market failure can be corrected by subsidizing some minimum amount for human consumption. Subsidies may introduce other distortions, however, and their costs must be weighed against the benefits of the health effects from consumption of safe water (Noll *et al*., 2000).

Studies from Europe throw useful insight into understanding the ways to do urban water demand estimation. The studies show that the per capita water demand had gone down in several European countries after economic restructuring took place during the 1990s, especially in the Baltic countries, and also due to demand reduction measures. Second: the per capita water demand in countries of warmer climate (South Western Countries) is much higher than that of countries of cold climate (Nordic and Central European countries). But, within regions, there are major variations. For instance, Nordic countries (Sweden, Iceland etc) have much higher per capita water use as compared to Central European countries (Germany, Ireland etc.) attributed to personal washing and dishwasher use. The lowest per capita use in Baltic countries is due to the peculiar institutional framework there, because of privatization of urban water supplies. The structure of water supply and water saving measures also influence the per capita use as demonstrated by the case of Ireland. It has a per capita water use of 125 $m^3$ per year against 68 for Germany, and Ireland does not levy any charges for water supplies (Source: EEA, 2003).

Table 1: Per Capita Annual Water Use in Different Regions of Europe

| Sr. No. | Name of the Region | Per capita Annual Water Use ($m^3$) |
|---|---|---|
| 1 | AC Northern | 95 |
| 2 | AC Southern (Turkey, Cyprus and Malta) | 68 |
| 3 | Western | 87 |
| 4 | South Western | 130 |

Source: EEA, 2003

Baltic countries (Estonia, Lithuania and Latvia, members of European Union) have the lowest water use per capita, together with Czech Republic, Poland and Hungary, which are part of AC northern region. The restructuring of the economy and the institutional framework in these three countries accounts for the decline. For instance in Hungary some of the water supply companies are privatised, the water service tariff is high and has had an important effect in urban water use. The Czech Republic water industry has been transferred

[3] Without incurring much expenses for water quality testing etc.

from the state to municipalities and different forms of ownership have been established, and water charges applied. In Baltic countries meters in private houses were installed, higher water tariffs applied and renovation of old pipe systems carried out, and all these measures have influenced the urban water use. Bulgaria, Romania and Slovenia (part of AC Northern) with 294, 123 and 124 $m^3$/inhabitant/y respectively, have the highest urban water use per capita (source: EEA, 2003).

Synthesizing these data from different regions with different climatic conditions, and institutional and policy environments, it appears that the impact of metering & pricing, and privatization of water supplies etc., would be significant in regions that have cold climates, and keeping higher tariff for higher levels of consumption might face greater resistance in warmer climates. A review of water pricing that prevail in French water utilities shows that flat rate are rarely adopted; declining blocks frequently used; and increasing blocks pricing which should be used to promote water use efficiency remain extremely rare (Montginoul, 2006). This means that while considering per capita demand rates for future water demand projections, lower values could be assumed for cold regions, if metering and volumetric water pricing are considered as demand management mechanisms.

### 5.2.2 Water Requirement for Improving Urban Environment

We have earlier mentioned that rising income levels would induce the demand for water for environmental services. One such service is growing trees in urban areas, the other being gardening. Among this, gardening can be a water-demanding activity in any kind of city, be it small or large, by the rich urban households. But, tree growing is essentially a business of the utilities in large cities with better economic conditions. The reason being that in small towns, the option of visiting country-side would be an easy option for the dwellers.

#### Urban Forests and Implications for Urban Environment and Water Demand in Urban Areas

One negative social consequence of urbanization probably is that social systems and attitudes may also be impacted with more urban people and more urban infrastructure (Egan and Luloff, 2000). Further, some sociologists think the fundamental processes of community development and community are negatively impacted by both unhealthy environments and the separation of people from nature and from each other in a growing suburbia (Wilkenson, 1990). Urban forests provide a multitude of benefits, including the reduction of energy costs through summer shade and winter wind protection (Abdollahi *et al.*, 2000; Akbari *et. al.*, 2001). Summer time studies have shown a 1° to 2°F (0.5° to 1.0°C) decrease in temperature for every 10 per cent increase in vegetation cover. Reducing temperature would have significant impact on water demand for domestic (air cooling, bathing and drinking) and commercial uses (air conditioning of office space, water for drinking and washing etc.).

Homes sheltered from the wind have winter heat savings of as much as 10.3 thousand BTUs (Nowak *et al.*, 1994). Also, there are growing opportunities for the use of urban wood and landscape waste for bio-fuels. Additional benefits of urban forests include slowing and reducing storm water runoff, flooding, reducing damage from cyclones, erosion, and reducing potential sources of water pollution. Hence, it might be ideal for high and medium to high rainfall areas and areas with rocky and undulating terrain like Hyderabad, which are susceptible to flooding.

Tree foliage works as a natural air filter of particulate matter and pollutants such as ozone, nitrogen oxides, ammonia, and sulphur dioxides (Nowak *et al.*, 2006). Foliar filtration, when combined with the intake of carbon dioxide and the production of oxygen through photosynthesis can have a significant effect on smog and reduce overall air pollution.

Through healthy places and increased interaction and decision making, trees and nature also play an important part in both increasing community capacity and the process of community development (Elmendorf, 2008). Accessible open space has been found to reduce chronic fatigue associated with urban life. Trees, shrubs, and related plants are valuable community assets that enhance neighbourhood beauty, recreational opportunities and wildlife habitat, and also provide city dwellers with opportunities to experience and understand forest-related benefits (Kuo and Sullivan, 2001). Nature also provides urban dwellers with safety and civility values including less domestic violence, general calming, and improved traffic safety (Kuo, 2003; Wolf, 2006). The urban forest provides significant economic values including increased property values (Irwin, 2002) and greater visitation and spending in forested commercial areas (Wolf, 2003). Urban forests also additional support represent an opportunity to engage a variety of stakeholders (citizens, civic officials, developers) in dialog about the value and function of natural resources. Although forest protection in urban settings can be contentious, a focus on shared values may generate for forest management activities (Thompson *et al.*, 2005).

But, trees also consume water. While providing environmental goods and services, they also impacts on water ecosystem. Therefore, it is very important to choose trees which have larger impact on creating shades, and which take less water; and make water use for growing trees very efficient from a physical point of view. Urban forest regeneration, for example, requires relatively large planting stock and often expensive installation. Program funding must include annual maintenance costs for utility line clearance, storm damage repair, debris removal, and protection from pests and pathogens. Long-term planning, appropriate tree species selection, care and management practices, and sustained local budgets would allow municipalities and communities to avoid crisis management (Hauer and Johnson, 2008).

## Estimating Water Requirement for Tree Plantation

Using a pan evaporation model created by others, Sivyer *et al.* (1997) developed a method for predicting irrigation amount and frequency for street trees and tested it on mulched, 3-in (7.5 cm) caliper, balled and burlapped *Pyrus calleryana* 'Redspire' (pear) and *Betula nigra* 'Heritage' (birch) trees five months after planting. The model predicted that root balls should be saturated every 3 days with 38 litres of water. When tested against control trees which were irrigated on an "as needed" basis according to root ball moisture sensors, model trees required a total 494 litre each of water, while pear and birch controls required an average of 410 and 464 litres each, respectively, over the experimental period of two months. However, pear and birch controls required 25 and 24 site visits respectively, whereas model trees required only 13 visits. Refitting the model assumptions with actual tree measurements and adjusting the root ball soil tension point at which root balls were to be irrigated to well above the permanent wilting point, resulted in a 19 litres, every 3 days.

Daily Transpiration = Crown Projection Area * Leaf Area Index* Transpiration Ratio * Potential Evaporation (PE) (Lindsey and Bassuk (1991)

The irrigation schedules would be determined by the root ball water storage and the transpiration. The challenges are in estimating water requirements of street trees are in estimating the actual leaf area index, and the water loss from root ball.

The experiment also shows that trying to quantify the transpiration losses on the basis of just soil moisture stress may not give accurate results, as there would be other losses from the root ball in addition to the evaporation loss (which is controlled through mulching here). The challenge is in arriving at estimates of the LAI, and CPA close to the actual figures.

### 5.2.3 Urban Water Demand Function

As the review of literature has shown, small towns in socio-economically backward regions are likely to experience high population growth due to low female literacy, lack of knowledge about reproductive health and high rural-urban migration owing to lack of employment opportunities in the rural areas. Contrastingly, small towns in other regions are experiencing very low growth in population due to poor infrastructure and employment opportunities. At the same time, the large cities everywhere in India are experiencing higher growth in population due to the tendency of industries to move to locations which are already having good manufacturing infrastructure and the consequent movement of populations in search of employment.

The urban water demand function (λ) can be estimated as follows:

$$\lambda = (\theta) * \psi$$

Where, $\theta$ is the population of a town at a given point of time, and $\psi$ is the per capita water demand in $m^3$/annum of that town.

For small towns in socio-economically forward regions, the population of a given town after "n" years $(\theta)$ is estimated as:

P*(1+μ) ^n: ......................................... (1)

Where, "μ" is the mean value of compounded annual growth rate in population estimated for 3 previous decades expressed in fraction; and P is the base population; "n" is the number of years for forecasting.

For large towns/cities and in small towns in regions which are socio-economically backward, the population of a given town after "n" years $(\theta)$ is estimated as:

P (1+ [X+¥]) ^n: ................................ (2).

Where X is the compounded annual growth rate in population of the previous decade expressed in fractions; and ¥ is the average increment in the compounded annual growth rate in decadal populations in four decades, also expressed in fractions.

### Per Capita Water Demand Projections

Since per capita water demand (normative) is a function of the population size itself, it is to be estimated after population projections. Since the provision of water for trees etc. is to be decided on the basis of city size, water demand projections are done for different categories of towns differently. Here, the environmental water demand is considered only for large towns (Class I) and metros.

Per capita water demand $\psi$ (m3/annum) for a town belonging to metros and Class I cities is estimated as:

$$\psi = ((€ * \theta) + \partial\theta * \Delta + \nabla * \theta + \propto)/\theta \quad \text{.................................... (3)}$$

Where, € is the per capita water demand for domestic uses applicable to those categories of cities and is expressed in $m^3$ per annum. In estimating the per capita water demand, a "correction factor" will be applied on the per capita water supply "norm" for the particular city/town category to factor in the influence of climate on domestic water demand. This "correction factor" will be estimated from the survey data by comparing the per capita use in cities/towns falling in different climates, but having adequate water supplies.

$\Delta$ is the per capita water demand for gardening estimated from the survey data for bungalows ($m^3$/annum); $\partial\theta$ is the fraction of the urban households living in bungalows; $\nabla$ is the per capita environmental demand for water ($m^3$/capita/annum), and it can be estimated from the survey data (climate-wise) or on the basis of the norm; $\propto$ is the industrial water demand estimated on the basis of industrial outputs generated within the town. The normative figures of industrial water demand per unit (ton) of manufacturing output for different industrial sub-sectors (17 of them) are provided in Table 2A below.

Table 2A: Water Use Rates for Unit Production for Different Industrial Production Units

| Sr. No. | Category of Industry | Water Requirement ($m^3$)/Ton |
|---|---|---|
| 1 | Integrated Iron & Steel | 22 |
| 2 | Smelters | 82.5 |
| 3 | Petrochemicals and Refinery | 17.0 |
| 4 | Chemicals-Caustic Soda | 5.5 |
| 5 | Textile & Jute | 20 |
| 6 | Cement | 4.5 |
| 7 | Fertilizer | 16.7 |
| 8 | Leather Products | 30 |
| 9 | Rubber | 6.6 |
| 10 | Food Processing | 6.8 |
| 11 | Inorganic Chemicals | 200 |
| 12 | Sugar | 2.2 |
| 13 | Pharmaceuticals | 25 |
| 14 | Distillery (Req. Per 1000 litres) | 22 |
| 15 | Pesticides | 6.5 |
| 16 | Paper & Pulp | 200 |
| 17 | General Engineering | 2.2 |
| | Total | |

Source: Report of the National Commission on Integrated Water Resources Development titled "Integrated Water Resources Development: A Plan for Action" (GOI 1999).

As regards per capita water demand for domestic uses (€) according to the Bureau of Indian Standards, IS: 1172-1993, minimum water supply of 200 litres per capita per day (lpcd) should be provided for domestic consumption in cities with full flushing systems. The bureau of Indian standards (1172-1993) further mentions that the amount of water supply may be reduced to 135 lpcd for the LIG and the economically weaker sections (EWS) of the society and in small towns (Modi, 1998). The Tenth Plan (2002-07), classifies the cities with planned sewerage system into two groups based on population, i.e., metropolitan or megacities and non-metropolitan cities. In the former, the recommended minimum water supply level is 150 lpcd and in the latter 135 lpcd (Table 2B). For non-metros without planned sewage, the recommended supply is 70lpcd (Govt. of India, 2002).

Table 2B: Normative Water Demand for Different Categories of Towns/Cities

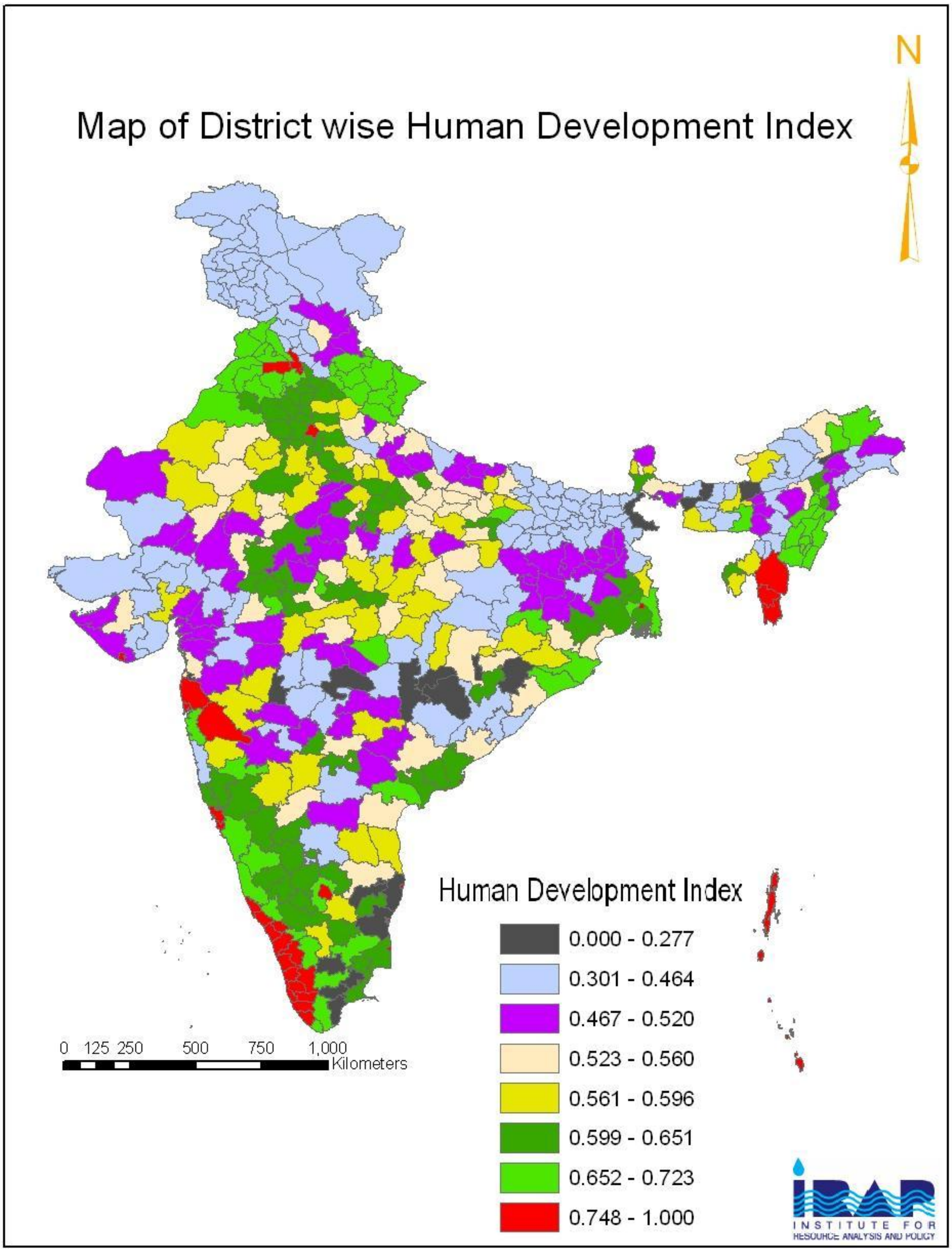
| Sr. No | City/Town Category | Per Capita Normative Water Demand for Domestic Use | Remarks |
|---|---|---|---|
| 1 | Metros (27 of them in India) | 150 | Presence of planned sewerage system |
| 2 | Non-metro cities | 135 | Do |
| 3 | Non metros without planned sewerage | 70 | Decentralized sewerage disposal system |

[1] While IUWM suggests that the cities/towns should have proper sewerage disposal and treatment system, under certain urban typologies, decentralized sewerage treatment system such as the septic tank will be adequate for small towns with low density of population.

## Socio-economic Development and HDI

As we have seen, the level of socio-economic development should be an important consideration for choosing the driver of population growth for any small town. The human development index can be a useful indicator of the level of socio-economic development of different regions as it captures the economic conditions, life expectancy and educational status, all three aspects of socio-economic advancement. Intuitively, it would also capture the female literacy, a factor, which has a bearing on future fertility rates, and population growth. This is because the regions of low female literacy also coincide with those which are socio-economically backward. Map 1 shows the HDI values for different districts of India, based on 2001 data. The districts that are having HDI values less than 0.50 are treated as "socio-economically backward", and those with HDI values exceeding 0.50 are treated as "socio-economically forward".

Map 1: Values of Human Development Index in Different Districts of India




## 6.0 ECONOMIC OPTIONS FOR URBAN WATER DEMAND MANAGEMENT

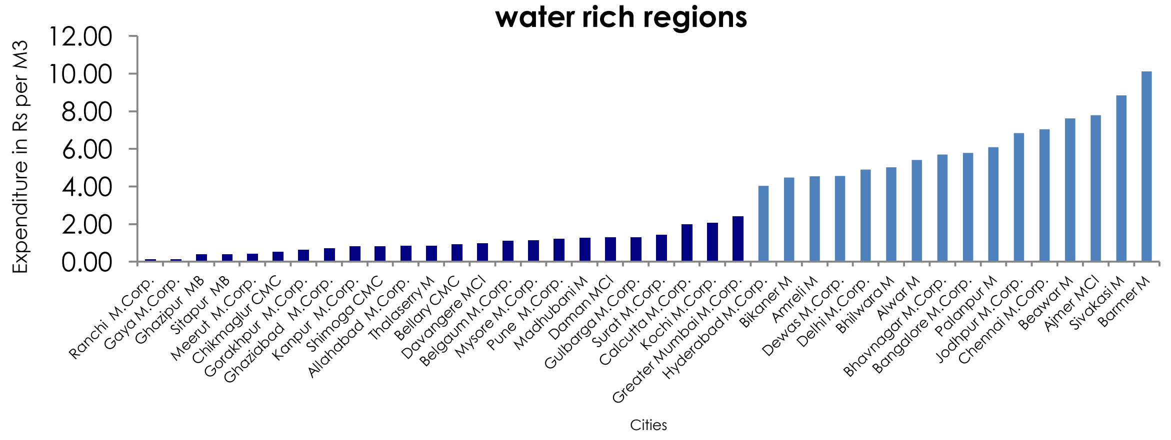
### 6.1 Cost of Water Supply Provision in Indian Cities

Analysis of data from 301 cities/towns belonging to Class I and Class II cities shows the following:

1. The cities which have very high density of population have as much high cost of production of water as those with low density of population

2. In cities with very high population (above 10 lac people), cost of production & supply of water is a direct function of the population size (logarithmic relationship).

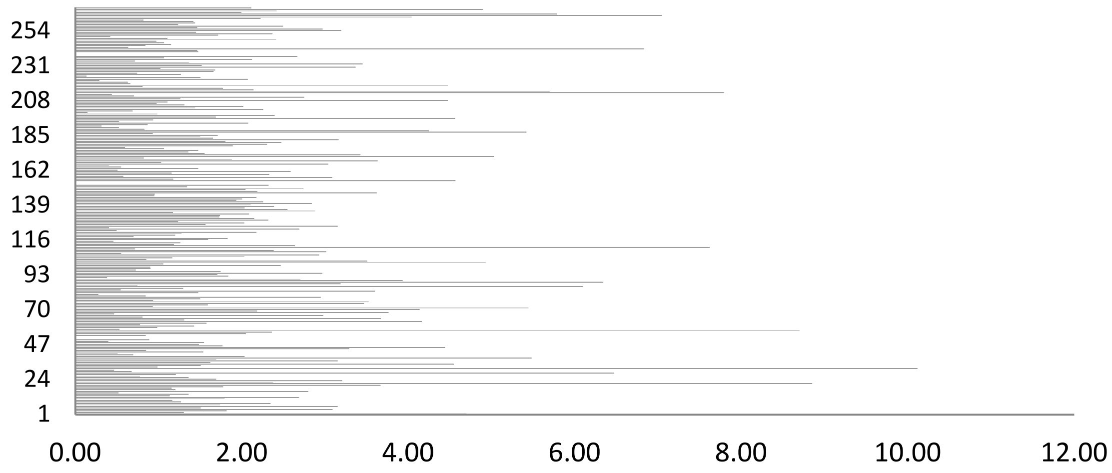
**Figure 2: Expenditure per cubic metre of water in water-scare & water rich regions**




3. The cost of production and supply of water is a very strongly influenced by the water scarcity situation. In regions which are naturally water scarce (and also experience physical scarcity of water going by Kumar *et al.*, 2008), the cost of production & supply of water is far higher than that of naturally water-rich regions (see Figure 2). The figure shows that the cities (23 nos.) that are falling in the naturally water-rich regions, have much lower cost of water supply (ranging from 0.05 to 0.88 Rs/$m^3$ of water) as compared to those falling in naturally water-scarce regions (ranging from 1.47 to 3.69 Rs/$m^3$ of water). The data on cost of water supply for 262 towns/cities are presented graphically in Figure 3.

4. One of the reasons for low influence of population density on cost of water supply is the effect of water-scarcity.

**Figure 3: Cost (Rs) per m$^3$ of water supplied across cities/towns: 261 nos.**




## 6.2 Price Elasticity in Water Demand

### 6.2.1 Pricing to Reduce Production Externalities

Domestic water consumption can be varied substantially by small changes in usage methods. Water is usually one input into a household production process, with opportunities for changes in input proportions in response to movements in relative prices. Moreover, part of demand is euphemistically called waste, i.e., a failure to fix leaking pipes, or to turn off taps after use. The price of water strongly influences these so-called water losses. An aspect of "waste", which is not widely recognized, is that if water is very inexpensive, "wasting" water is perfectly rational. If the price of inexpensive water simply reflects the fact that it is plentiful and its delivery costs are very low, then "wasting" water is inefficient only if creates a significant external diseconomy, an issue that is explored in the next section.

This conclusion applies to both consumers and water utilities. A frequently used indicator of the efficiency of a water utility is its proportion of “unaccounted for water” (UFW). One source of a (UFW) is a leaky distribution system. Fixing these leaks is a substitute for expanding diversion, storage, transportation, treatment, and distribution capacity. Repairing leaks is worthwhile only if the value of the water saved justifies the investment in new pipes, which may not be the case if plentiful, high-quality water is available nearby. The other important implication of demand that exhibits some price elasticity is that a mistake in pricing can have large consequences for water use. Prices that are too low create a demand to expand water delivery beyond the efficient point. If the costs of the water system are not primarily financed by water revenues, but by general taxes or revenue from another utility, under-pricing water can be very expensive to society as it would mean massive, uneconomic expansion of the water delivery system.

There are issues with pricing water. The first one concerns what component of the cost should be included in water pricing. If water prices have to cover all costs and if costs are high due to inefficient or corrupt management, much economically warranted water usage can be cut off, and a small improvement in the efficiency of the operation of the water utility can yield large economic benefits.

Another problem concerns with the consumers not valuing water quality high enough. This can be because of information imperfections. Some users may lack understanding of the relationship between water quality and health. Others may understand these relationships in principle, but they cannot effortlessly[4] observe aspects of poor water quality such as the presence of microorganisms or trace chemicals that are health hazards. If the effective demand for quality is too low because of information imperfections, consumers may respond to higher prices for piped water by consuming too much low-quality water from contaminated alternative sources. This market failure can be corrected by subsidizing some minimum amount for human consumption. Subsidies may introduce other distortions, however, and their costs must be weighed against the benefits of the health effects from consumption of safe water.

### 6.2.2 Pricing to Reduce Usage Externalities

The purpose of urban water systems is to increase the availability of water at relatively low cost, thereby expanding the uses of water. This expanded usage inevitably increases the amount of polluted water that a community produces. Water that is polluted through use often simply returns into the natural environment through nearby stream, lake, ocean, dry canyon, cesspool, or vacant plot of land. The external costs imposed by water pollution depend on the circumstances surrounding its disposal. Whereas all pollution will have some effect on the natural environment, the cost depends on the value of the environment for other uses.

The most important source of the costs of pollution arises from the exposure of human populations to unhealthy pollutants, either by polluting the environment in which they live or by polluting their food and water sources. Research on the effects of improved water systems demonstrates that simply increasing the quality of water at the point of consumption is not very effective in improving the health of the population. For example, a careful study of water and sanitation systems in eight developing countries found that improved wastewater and sanitation policies significantly improved the health and body weight of children, especially in urban areas, and that improvement in the quality of delivered water improved health only if accompanied by improvements in sanitation (Esrey, 1996). One family cannot capture the benefits of sanitation by installing sewage disposal if all around it are dumping their wastes in the neighbourhood; hence, even with perfect information, private incentives to install sewage are less than its social value.

If either users or water utilities are not held accountable for the costs that they impose on others, they will overproduce pollution and use an inefficiently large amount of water for polluting purposes. The economist's stock solution for this problem is to impose a tax on pollution that fully reflects the marginal cost of pollution on others (see Baumol and Oates, 1988, and Cropper and Oates, 1992). Taxes create a financial penalty for water pollution, and so provide a financial reason to invest in either sewers or water treatment facilities. These investments, in turn, will raise the price of water use, and so curtail consumption and the pollution that it creates. Users and water utilities will then have an incentive to cut back on polluting uses of water, and to treat waste water to remove pollutants, until the marginal cost of abatement equals the marginal cost of pollution. If instead of using taxes the government issues regulations that require these investments, the utility has a financial incentive to delay taking actions (to postpone costs) and to undertake the minimum actions that are consistent with the law. The decision about the level of tax to impose (or, more generally, how much abatement to require) is subject to distortions in the

[4] Without incurring much expenses for water quality testing etc.

political process. Of course, distortions in the political process may cause the government to demand too much rather than too little abatement. In addition, political distortions also may misallocate the burdens of pollution and pollution abatement for the same reason that they can distort the price structure.

The pollution issue raises a problem of institutional design: how can government commit to a long-term pollution policy that reduces the harms from pollution while avoiding overzealous pursuit of environmental policy that indirectly expropriates the investments of the water utility? The optimal design of environmental policy institutions and instruments is beyond the scope of this paper; however, an essential part of the assessment of the performance of an urban water system is whether this problem has been addressed in a reasonable way.

## 6.3 Status of Water Metering and Pricing in Indian Cities

Several Indian cities meter water consumption at the end of the consumer connection. For instance, Hyderabad Metro Water Supply and Sewerage Board (HMWSSB) meters domestic consumption for individual bungalows and for bulk consumption at the level of individual apartment blocks. A recent survey showed that 60% of the water consumption in the metro cities in India is metered. According to a 2002 study of 300 cities about 62% of urban water customers in metropolitan areas and 50% in smaller cities are metered. Users of stand posts receive water free of charge. A 2007 study of 20 cities by the Jawaharlal Nehru National Urban Renewal Mission with the support of the Asian Development Bank (ADB) showed that only 25% of customers of these utilities were metered. Most other customers paid a flat tariff independent of consumption. Some utilities, such as the one serving Kolkata actually do not bill residential users at all

Domestic water supply is highly subsidised in many Indian cities, including Kolkata, Bhopal and Indore (see Table 3). Though in many cities, the average water tariff is higher than the cost of production & supply of water, the high average is because of high tariff levied from industries and commercial connections, and domestic supply is actually heavily subsidized (source: ADB, 2007). The second factor is water supply administration. Domestic water supply is not fully metered even in large cities. In more than 50% of the cities falling under Class I and Class II category, household connections are our partially metered or un-metered (source: based on data presented in NIUA, 2005). The third factor is the way water tariff is administered. Many large cities viz., Kolkata, Jabalpur, Jamshedpur, Mathura, Rajkot, Varanasi, Bhopal and Indore meter only less than 1% of the connections, whereas cities such as Ahmedabad, Vijayawada, Amritsar, Chennai, Surat and Visakhapatnam meter 1-10% of the connections (ADB, 2007: pp 22).

Table 3: Cost of Production of Water and Water Tariff in 20 Indian Cities

| Sr. No | Name of the City | Average Water Tariff ($Rs/m^3$) | Average Cost of Production of Water ($Rs/m^3$) |
|---|---|---|---|
| 1 | Bhopal | 0.6125 | 3 |
| 2 | Mathura | 0.612 | 2.2 |
| 3 | Kolkata | 1.25 | 3.5 |
| 4 | Ahmedabad | 1.5 | 1.5 |
| 5 | Jabalpur | 1.6 | 1.8 |

| | | | |
|---|---|---|---|
| 6 | Surat | 1.7 | 2.1 |
| 7 | Vijayawada | 2.5 | 2.25 |
| 8 | Indore | 3 | 13.2 |
| 9 | Varanasi | 3.12 | 2.25 |
| 10 | Coimbatore | 3.75 | 1.5 |
| 11 | Nashik | 4.2 | 2.15 |
| 12 | Jamshedpur | 4.32 | 2.5 |
| 13 | Mumbai | 4.4 | 3.75 |
| 14 | Chandigarh | 5.05 | 4 |
| 15 | Rajkot | 5.05 | 2.85 |
| 16 | Nagpur | 6.5 | 2.15 |
| 17 | Vishakhapatnam | 8.5 | 4.9 |
| 18 | Amritsar | 9.32 | 4.5 |
| 19 | Chennai | 10.8 | 6.05 |
| 20 | Bangalore | 20.5 | 10.2 |

Source: derived from charts in ADB, 2007

Often the use of block rates in urban water pricing causes the poor people to pay more for water creating negative impacts on access equity (UNDP, 2006:pp). The factors that make the poor pay more for water needs to be understood. One of the problems facing urban water utilities is the poor infrastructure, with low percentage coverage of individual water supply connections. The people living in city slums, who account for a major chunk of the population, access water from public systems through common stand-posts and taps. Due to the limited amount of water that is accessible through common taps, they have to manage their water supplies from a myriad of sources such as water tankers; private water vendors; and fetching water from long distance sources, spending substantial amount of time and labour. It is also important to note that water supply from public systems is the cheapest, and the costliest being the water supplied by vendors (UNDP, 2006).

A study carried out for the *White Paper on Water in Gujarat* among urban populations showed great inequity in access to water supplies between different classes. In Bhuj town, the Municipality supplies water to the town's population through the piped water supply with individual tap connections in housing societies, commercial establishments and other government and private establishments. Stand posts are maintained for water supply to slum areas. In Bhuj town, the average domestic water use was 14 lpcd in the slums, while it was 79 lpcd in middle class housing societies and 109 litres in upper class societies. Since the water charge is not levied on volumetric basis, and instead is linked to property tax, the supply costs the poor slum dwellers much more than what it costs for the economically rich people enjoying independent tap connections in urban areas. In Rajkot city, while the Municipality supplied water through tankers to housing stocks during drought years, a large section of the city's residents was dependent on private water tankers paying high prices**.** The slum dwellers were using 18 lpcd of water a day on an average, against 63lpcd by middle class societies and 83lpcd by upper class societies (IRMA/UNICEF, 2001).

While incremental block rates are advocated for urban water supplies for bringing in equity in access to water, efficiency in water use, and improve affordability, they are not widely practiced. One major reason is the poor coverage of public systems vis-à-vis individual connections. As studies from Bangalore, Kathmandu, Bogotá and Chile show, if the private connection charges are low, incremental block rates can produce undesirable equity consequences with a disproportionately larger share of the water subsidy benefits going to the richest and the middle income groups (Komives *et al.*, 2005 as cited in UNDP, 2006: pp99). The ability of resource rich urban dwellers to access water from private sources such as wells is another issue in proper pricing.

Hence, the issue is also about building adequate water supply infrastructure and creating sufficient incentive structures, apart from administering water supply, and introducing an efficient tariff policy to address efficiency, affordability and equity concerns and administering it.

## 6.4 Norms for Fixing Prices of Urban Water Supplies and Sewerage

The norm for fixing prices can be based on certain sound principles and objectives. Financial cost recovery is an interim objective in urban water pricing. In the long run, the objective of pricing should be such that it reflects the increasing long-run marginal costs of water supply and its disposal, specifically addressing the costs of environmental damage in production and consumption, and the opportunity costs of depletion. This is referred to as marginal opportunity cost of production (MOCP). The MOCP has inbuilt economic efficiency and financial cost recovery considerations.

But, the community may not be willing to pay the marginal opportunity cost of production of water (MOCP) due to problems of affordability. Hence, the norms for price fixing can be arrived at by integrating the concerns of affordability and equity with economic efficiency and full cost recovery considerations that are reflected in the long term marginal cost estimates.

This can be defined as: MOC = MDC + MEC =MUC

MDC =Marginal Direct Cost (of the resources needed to supply water & provide the sewerage treatment facility)

MEC = Marginal External (Environmental & Social) Cost due to the negative impacts on environment and society owing to reservoirs, ecological damage, pollution from sewage etc.

MUC = Cost of using/depleting the resource

The cost of using/depleting water would vary from region to region, but would be highest in the most water-scarce regions. This would however, be determined by the alternatives uses of water that exist in the region under consideration. Some evidence about the depletion cost of using water in water-scarce regions is obtained from a study of the Hai River Basin. This region has the most severe water related problem among all major water resource regions in China. However, while water production costs, at 5.08 yuan/ cubic meter, are relatively high, they are minimal in comparison with the potential costs of a water shortage in the region. The study estimates the economic value of water (EVW) - or opportunity cost - in terms of value added in alternative industrial or agricultural uses, and finds that the average EVW for economic sectors based on integrated water withdrawal in eight study areas to be 41.8 yuan/cubic meter, in which that for tertiary industry is as high as 208 yuan/cubic meter, the next highest is for construction at 180 yuan/cubic meter, the third is for mining and quarrying at 114 yuan/cubic meter and the lowest is for various agricultural uses, ranging between 3–16 yuan/cubic meter. There is considerable variation in EVW between different areas, with the average EVW in Beijing being the highest and that in Xinxiang is lowest.

Not only the cost of depletion but also the marginal direct cost of production (MDC) of water also could vary significantly from region to region as shown in the analysis in section 6.1. It shows that the average direct cost of production and supply of water varies significantly from water-rich regions to water-scarce regions.

The marginal opportunity cost pricing could be used for deciding prices for uses far in excess of the basic needs within domestic sector (for instance, car washing, irrigating gardens, lawns etc.), and commercial and industrial sectors. Such prices would be far higher than those fixed for achieving financial cost recovery. But, in the case of low income groups needing water to meet low levels of demand, a lower tariff could be used for domestic water supplies. The long term marginal cost can be estimated by taking a 20-year time frame.

Metering is clearly required for introducing volumetric block rates. But, metering decisions must be subjected to cost-benefit analysis and introduced on a case-by-case basis. The case for metering will become strong as both incomes, and water supply & disposal costs increase. The reasons are two: First: the cost saving and economic/social benefits from reduction of wastage and effluent load would increase with increase in marginal opportunity costs of production of water (MOCP). Second: the feasibility of introducing meters and volumetric pricing would increase with increase in income, as affordability would be higher at higher incomes. Such a policy may possibly be complemented by parallel targeted and temporary income support programs or vouchers to be exchanged for water and sanitation service.

It is good to start metering individual domestic users, and commercial and industrial users. In cities where majority of the population live in apartments, pricing bulk users would be the only option for charging for domestic water supplies. But, this would call for creating new institutional mechanisms at the level of the user group.

Given the politically infeasible nature of tariff rise, a gradual approach to price reform would always be desirable (World Bank, 2007). This was tried in the case of Gujarat, India for canal water pricing. The state government now revises the tariff once in every year, with 10% rise. Public hearings, consumer education, and transparency are necessary to overcome resistance to price reform, especially when the quality of the existing service is poor. Often the consumers are not informed about the various components of the charges the utility levy; the actual cost of the services provided, and the level of subsidies given; and how they have been arrived at.

Since the late 1970s, water has been priced volumetrically in Beijing. Prior to 1997, the pricing policy in Beijing did not embrace the concept of full cost recovery, i.e. recovery of capital, operations and maintenance costs (O&M), and wastewater treatment. Since 1997, however, the real price of water in Beijing has increased sharply.

Furthermore, in 1998, an additional volumetric tariff for wastewater treatment was added. In addition to covering the cost of supply, the water laws, policies, and regulations are very much concerned with water saving and conservation and the protection of water resources. In this sense, pricing has also been promoted as an instrument of water demand management. The price of water in Beijing reflects a number of different cost items. For example, the tariff in 2003 was 2.9 yuan/cubic meter. This consisted of a water resource fee (for both surface and groundwater) of 0.6 yuan/cubic meter, a sewage treatment fee of 0.6 yuan/cubic meter, a tap water fee of 1.7 yuan/cubic meter to cover the fixed and variable (capital and O&M) costs of the water supply company, and a tax of 0.33 RMB/cubic meter paid to the Beijing municipality. This breakdown reflects the structure stipulated in China's Price Law and the National Guidelines on Water Tariffs.

At present, the price of water in Beijing is the highest in all the cities in China and recent price adjustments for the residential sector have been focused on the sewage treatment fee and water resource charge, rather than the tap water tariff. Despite these reforms, including a further increase in the residential water tariff to 3.7yuan/cubic meter in 2004, water and sewerage in Beijing remain subsidized even in strictly financial terms.

Under the European Water Framework Directive, some European countries use different kinds of norms for charging water services. For instance, the Dutch government uses the abstraction taxes which are reflective of the environmental cost of pumping groundwater. The rates are given in Table 4A.

Table 4A: Groundwater Abstraction Taxes in the Netherlands for Different Sectors

| Sr. No | Water Charges | Rate |
|---|---|---|
| 1 | Standard Rate | € 0.15/m3 |
| 2 | Agriculture/Industry | € 0.08/m3 |
| 3 | Infiltrated Groundwater | € 0.025/m3 |

Source: Pierre Strosser (undated)

## 6.5 Water Metering and Water Pricing under IUWM

Metering will help reduce unaccounted for water in utilities[5]. Pricing of water on the basis of volume of use, for which metering is a pre-condition, will encourage urban water users to prevent wastage, thereby saving on their monthly water bill. Metering water supplies and charging on volumetric basis are cost affairs, and therefore should be based on benefit-cost calculations.

The foregoing analysis suggests that it would make economic sense to do metering in cities/towns falling in regions that are water-scarce. The reasons are two: 1] the cost of production and supply of water is high in such regions, which makes the net cost saving from prevention of thefts significant, thereby justifying the high cost of installation of meters and meter reading; and, 2] improved efficiency of water use achieved through volumetric pricing leads to greater social benefits, as both the resource depletion cost and cost of environmental degradation would be high in water-scarce regions. Nevertheless, in the case of small towns in water-scarce areas that are less urbanized, the % UFW and affordability should be considered. If affordability is poor, then prices have to be brought down across the board.

Whereas in a water-rich area, though normally the cost per unit volume of water would be low, it is also found to be increasing with increase in size of population (source: authors' own analysis based on 301 town data). Therefore, it is important to do metering and volumetric pricing in large cities falling in such water endowments. Further, metering and volumetric pricing would be more feasible in cities with high average per capita income. The reason is high per capita income increases the affordability of the water which becomes expensive as the cost of metering gets transferred to the consumers. The amount of UFW (aggregate volume) also would be high owing to large geographical areas. Whereas in small towns, the decision to install meters and price water volumetrically should be based on an assessment of unit cost of production & supply; and the total volume of water lost as UFW which ultimately determine the revenue losses. Besides these, in small towns which are less urbanized, affordability and the political will should be factors to be considered over and above the three factors mentioned.

Table 4B: Technical and Economic Considerations in Deciding on Water Metering in Urban Areas

5 While it would reduce the administrative losses, it would also help us assess the amount of water lost in pipe line leakages.

| Criteria for Selecting a Utility for Metering & Volumetric Pricing | Overall physical, socio-economic and political set up | | | | | |
|---|---|---|---|---|---|---|
| | Water-scarce | | | Water rich | | |
| | City including metro | Small town | | City including metro | Small town | |
| | Urbanized | Urbanized | Less urbanized | Urbanized | Urbanized | Less urbanized |
| Unit cost of production | | | | | | |
| % of UFW | | | | | | |
| Volume of water supplied | | | | | | |
| Affordability | | | | | | |
| Political will | | | | | | |

Note: the shaded cell indicates that the particular criterion is relevant.

The matrix in Table 4B shows that in a water-scarce area, unit cost of production and the volume of unaccounted for water (UFW) are not to be considered before going for metering and volumetric pricing. The same is the case with a large city in a water-rich area also. Whereas in a small urbanized town located in a water-rich area, the unit cost of production; % of UFW and the volume of water supplied need to be considered before going for decision to do metering & volumetric pricing.

Political will matters in less urbanized towns (with low per capita income) for utilities to go for metering & pricing, especially when there is no physical shortage of water.

## 6.6 Building Public Consensus on Raising Water Tariff: Chinese Experience

In India, attempts to raise water and electricity tariff is often met with a lot of political resistance and community protests. In some case, governments have to roll back the decisions to raise tariffs.

An attempt to obtain public support for price increases that were required to provide funding for improvement and expansion of facilities in Chongqing received a hostile reception at public hearings. Consequently, the Chongqing municipal government conducted a research effort to facilitate a public awareness campaign. This was aimed at educating the population about the costs of supplying water and managing wastewater generated in the city and the impact on service quality if the municipal water supply system was unable to increase revenues. It showed that the primary losers when prices are too low were the poor, whose service standards remained inadequate. Indeed, the wealthier consumers, who consumed the most water, were the biggest beneficiaries from the subsidies involved. In addition to the educational process, and in recognition of the problems the poor had in paying higher water prices, the Chongqing municipality decided to implement a number of parallel subsidies for disadvantaged groups including the unemployed which would be sufficient to maintain basic living standards which included paying the increased water bills. The study also recognized that a step-by-step approach must be used, and a schedule for gradual increases in prices over a number of years was introduced. Since the public was made aware of the findings of the study and in particular the rationale for the price increase, subsequent public hearings attended by representatives of disadvantaged groups were very constructive. The process was instrumental in making the required price increases socially acceptable, and the reforms have apparently been effective in reducing water consumption in the city (World Bank, 2007).

The recent experience of Kerala water board is an illustrative example of how public perceive the water tariff reforms. It is important to study how the government is going ahead with its plan to raise the tariff.

## 6.7 Impacts of Abstraction and Pollution Taxes & Need for Social Audits

In wastewater pricing, the volume of water consumed for domestic purpose can be used as the basis for fixing the charges for wastewater across urban households, as the quality of wastewater from households remain more or less similar. But, in case of industries, the effluent quality can vary across industrial units. Hence, the pricing has to be based on both volume of effluent and the type of pollutant. The norms for effluent discharge used by some European countries namely, Denmark, Germany and Holland are given in Table 5.

Table 5: Effluent Discharge Norms for Selected European Countries

| Name of the Country | Parameters | Charges | Goes to |
|---|---|---|---|
| Czech Republic | Organic matter | • 0.24 €/kg for treated wastewater<br>• 0.53 €/kg for un treated wastewater | State Environment Fund |
| Denmark | Nitrate, Phosphate, Organic matter | • 2.7 €/kg of nitrates; 14.7 €/kg of phosphate; 1.5 €/kg of organics | Central budget |
| Germany | Pollution Unit | 36 Euro per damage unit | |

Source: Pierre Strosser (undated)

Note: 1 pollution unit is equal to 25 kg of nitrate; 20 gm of mercury

The full desirable impacts of imposing abstraction taxes and pollution taxes would be achieved only if all the users (at all levels) of the water are confronted with the opportunity costs of the particular usage. It is understood that with the imposition of taxes, the users would have incentive to reduce the wastage. But, the water utility would have strong incentive to reduce the wastages, only if they pay for every unit of water they divert to the agency which is concerned with resource management. Again, it is important that the agency which finally collects the fee/tax diverts the money for the purpose for which it was meant. In fact, what is more important than just levying the abstraction and pollution taxes (as found in the case of European countries and China) is in making sure that the funds are used for corrective measures rather than enriching the state exchequer. As Table 6 indicates, out of the four countries, only in Denmark and France, the funds raised are used for the right purpose.

Table 6: Utilization of Abstraction/Pollution Tax in Four Countries

| Country Name | Charged for | Rate | Earmarked for |
|---|---|---|---|
| Denmark | Sewerage Discharge | 100% | Municipal wastewater treatment project |
| Estonia | Water Abstraction | 50% | Environmental protection; balance |

| | | | |
|---|---|---|---|
| | | | 50% for local budget |
| France | Water Abstraction | 100% | Water quantity management |
| England/Wales | Water Resource | 100% | Recovery of government costs for water management |

Source: Strosser (undated)

## 6.8 Differential Impacts of Regulations and Economic Instruments

The comparison between the policy measures adopted in the Netherlands and Denmark that brings out the clearest lessons about how MBIs can be useful in both applying the polluter pays principle and in achieving reduction of pollution at source.
Already from the 1970s – so before the introduction of the directive - the Netherlands adopted both full cost user fees, for access to water treatment plants, and realistic levies on discharges of pollution to open water, based on the polluter pays principle.
The revenues were then used to construct water treatment plants and crucially also to provide technical and financial support to help the most polluting industries to install cleaner technologies – for example the food, chemicals and paper industries. Together with substantial pollution levies, discharges of polluted water was reduced, which then in turn required less treatment plant to be constructed.

By contrast, Denmark mainly invested in end-of-pipe public water treatment plants until around the mid-1990s when they introduced pollution levies and clean technology support programmes. By then, however, most treatment plants were already constructed, and had begun to generate additional operating and maintenance costs.

The most important reasons for the different experiences of these two Member states were the early use in the Netherlands of full cost recovery user fees and realistically high levies on pollution combined with the targeted application of their recycled revenues – in other words "hypothecation" - to support eco-efficiency measure Social auditing would be required to make sure that: the costs shown by the utilities are real and reasonable and fall within the cost norms fixed for various items; and the funds generated from water tax, are utilized for the purpose for which they are meant. The abstraction tax for groundwater should be utilized for actions for improving groundwater management that reduce the negative environmental effects. The social auditing should also make sure that they are no double counting of costs. For instance, environmental cost of water supply does not get justified if the full cost of treatment of sewage is charged from the users[6].

Holland's groundwater tax has resulted in water savings from 2 to 12% from 1995 levels for industry (but many exemptions, and no information for household use); Water prices increased by 110% for self abstractors, but overall tax less than 0.1% of Dutch industry value added self. Leakage reduction in water supply systems by 23% was observed in Denmark (1993-1998) as result of water supply tax introduced in 1993 (Strosser, Undated).

## 6.9 Incentives for Increased Use: Urban Water Pricing Structures in France

6 Speech by Professor Jacqueline McGlade Executive Director, European Environment Agency at "The Brussels Tax Forum: Taxation for Sustainable Development," Brussels 19 March 2007.

The objectives and criteria for fixing water tariff cannot be the same across cities, particularly when there are sharp differences in the resource endowment and the cost of production of water even when only direct costs are considered.

In the large majority of French cities and towns, water is charged with a two-part structure: a fixed part and a proportional part. The volumetric rate is only found in 3% of French districts (representing 6% of the population). The flat rate structure remains anecdotal, concerning only 3% of French districts (rural), which hardly represents a few per mile of the population (Montginoul, 2006).

The fixed part corresponds, on average, to a volume consumed of 23 $m^3$. This average ratio is higher (b/a =46) in districts without collective sewerage (and also smaller). Proportional water part charged to users is constant in 57% of the districts, corresponding to more than 70% of the population. Surprisingly 36% of the districts use declining block tariff structure and only 1% (5% of the population) an increasing block structure. Declining block rate is especially found in small districts where it is probably implemented to maximise sales and to secure cost recovery. Such modes of pricing can be adopted when the supply infrastructure is able to accept increased load, and the marginal cost of production of water is very small (Montginoul, 2006).

## 6.10 Empirical Data on Price Elasticity of Urban Water Demand

Field based research was carried out in three metropolis of South Africa to estimate the price elasticity of urban water demand for domestic purposes, covering high income, middle income and low income groups. The cities are: Cape Town; Tshwane; and Ethekwini. The estimates of price elasticity of water demand for different segments of the society for these three towns are given in Table 7.

Table 7: Price Elasticity of urban Water Demand in three South African Metropolitan Cities

| Income Groups | Total price Elasticity of Demand | Range of Values Falling within 95% Confidence Level |
|---|---|---|
| Low Income Groups: | | |
| Tshwane | -0.365* | -0.227, -0.502 |
| Cape Town | -0.110 | -0.048, -0.290 |
| Ethekwini | -0.130 | -0.038, -0.195 |
| Mid Income Groups: | | |
| Tshwane | -0.167* | -0.022, -0.191 |
| Cape Town | -0.101 | -0.025, -0.177 |
| Ethekwini | -0.134 | -0.012, -0.161 |
| High Income groups: | | |
| Tshwane | -0.116* | -0.039, -0.220 |
| Cape Town | -0.087 | -0.048, -0.223 |
| Ethekwini | -0.137 | -0.050, -0.225 |

Source: http://www.fwr.org/wrcsa/1296104.htm

Note: * = Statistically significant difference (on a 5% level) in price elasticity between low, middle, and high income.

From the results of the CV experiment certain tariff policies were suggested and also some advice was offered on water system design and the price of water. With respect to tariff design, it was suggested that tariff should cover all costs, they should be made as simple as possible, that they should be collected regularly emphasising that a sound tariff policy should promote the efficient use of the resource and provide an adequate service to all its consumers. The question of cross subsidisation and tariff design was considered and it was pointed out that cross subsidies can create serious distortions that affect the efficient use of water and they require a considerable administration structure for them to effectively manage (Source: www.fwr.org/wrcsa/1296104.htm).

With respect the design of water resource developments, the price elasticity of demand found from the CV experiment could be used by designers to use investment funds efficiently by means of staged system design, thus using the funds available in the most efficient manner.

Olmstead *et al.* (2007) estimated the price elasticity of water demand with household-level data, structurally modelling the piecewise-linear budget constraints imposed by increasing block pricing. They developed a mathematical expression for the unconditional price elasticity of demand under increasing block prices and compared conditional and unconditional elasticity analytically and empirically. They tested the hypothesis that price elasticity may depend on price structure, beyond technical differences in elasticity concepts.

The study involved 1082 households from 11 urban areas in the US and Canada served by 16 public utilities. The study found that the price elasticity of water demand was higher under increasing block prices (IBP), than under uniform (marginal) price. This could not be explained by the differences in average price of water between the two situations. The demand elasticity was 0.59 under IBP, against 0.32 under UP (Source: Table 3, pp190). Due to the possibility of endogenous utility price structure choice, observed differences in elasticity across price structures may be due either to a behavioural response to price structure, or to underlying heterogeneity among water utility service area.

Renwick and others (1998) formulated an econometric model to assess the potential of price policy as a residential water resource management tool in California. This econometric model explicitly incorporates alternative demand side management (DSM) policy instruments, endogenous block pricing schedules, and a Fourier series to separately capture the effects of seasonality and climate on residential demand. The analysis relies on agency-level cross-section time series data for eight water agencies in California representing approximately 7.1 million people or 24% of the total population.

The estimation results suggest that price is a moderately effective instrument in reducing residential demand within the observed range of prices. The coefficient on the marginal price of water is, as expected, negative and statistically significant. The estimated own-price elasticity of demand equals **-.16**, implying a 10 percent increase in price will reduce the aggregate quantity demanded by 1.6 percent. Isolating seasonal own-price elasticity indicated that the own-price elasticity of demand for the summer months (June - August) equals **-.20**. These own-price elasticity estimates are within the order of magnitude of previous studies[7]. While drawing policy inferences from these results, it is important to remember that the estimated own-price elasticity are only valid within the region of observed marginal prices which ranged from $.47 to $4.25.

In addition, estimation results indicate that alternative DSM policy instruments (such as public information campaigns, retrofit subsidies, water use restrictions and rationing)

[7] The estimated own-price elasticity are slightly less than those previously estimated for urban areas in California, which range from -.22 to -.37 (Renwick (1996), Renwick and Archibald (1998) and Berk et al. (1980)) perhaps due to the exclusion of alternative DSM policy variables (Berk et al., 1980) and the significantly larger range of marginal prices (Renwick (1996) and Renwick and Archibald (1998)) in these other studies.

reduced residential water usage. The estimated coefficients on the public information campaigns, retrofit subsidies, water rationing and water use restrictions, policy dummies were all negative and statistically significant. The magnitude of the estimated coefficients indicated that more stringent mandatory policies, such as use restrictions, reduced demand more than voluntary measures, such as public information campaigns. While these results provide further empirical evidence regarding the effectiveness of alternative DSM policy instruments, they must be interpreted with caution due to the aggregate nature of the data and definition of policy instruments. The remaining two DSM policy dummies (*REBATE* and *COMPLY*) were not statistically significant, probably as a result of aggregating the policies across several agencies and definition of when the policy was in effect

A survey of the quantities of water purchased from vendors in the squatter areas of Khartoum, Sudan, was used to assess the effect of water price and household income on domestic water consumption. Households in two squatter communities--Meiyo and Karton Kassala--were studied by observation and by interview. In spite of the substantially higher charges, water consumption in Karton Kassala was as high as that in Meiyo. Households within these communities showed no tendency to use less water when paying a higher price for it, or when their income was below average. In other words, no price elasticity or income elasticity was detectable. This was all the more striking in view of the high proportion of income that was spent on water; 17% in Meiyo, and 56% in Karton Kassala. One consequence of this lack of elasticity is that the poorest households devote the greatest percentage of their income to the purchase of water, although the only major item in their household budget which can be sacrificed to make this possible is food. The high price of water in urban Sudan is probably a major cause of the malnutrition prevalent in the squatter areas. Another consequence is that a low-income household's consumer surplus for domestic water is very high, amounting to a substantial proportion of its total income. This has important consequences for the economic appraisal of urban water supply schemes. It also follows that wealthier households with private connections would be willing to pay at least as much for water as that currently paid by the poor.

## 7.0 PHYSICAL OPTIONS FOR WATER SUPPLY MANAGEMENT

In this section, we would discuss the strategies for improving effective availability of water in terms of quality and quantity in urban areas for sustainable water supplies. First among them is the integration of various physical components of the hydrological system in the planning and development of water resources. Protecting the quality of available water is another important aspect of sustaining the effective water availability for urban water supplies, and hence is part of the physical option. In addition, there are many options to augment the supplies, such as storm water management and roof runoff harvesting. They would also be discussed.

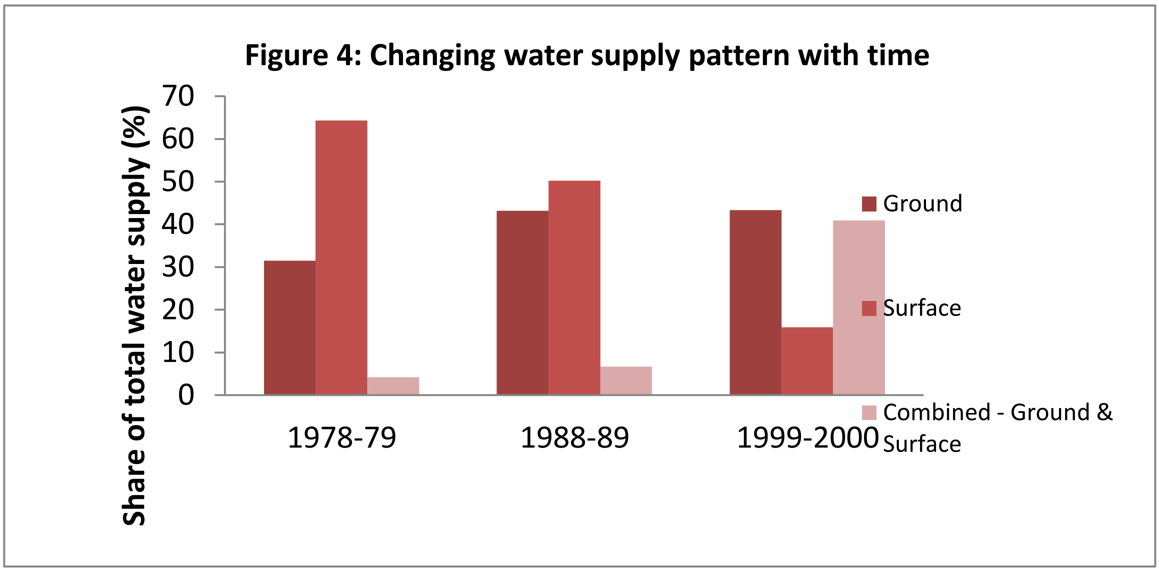
### 7.1 Physical Options for Water Supply

The analysis of data available from 301 towns and cities across India on water supply, cost of production & supply of water, bring out the following interesting facts about urban water supply. The cost of production of water is heavily dependent on the overall water situation. In water-scarce regions, the cost of production of water is high, whereas it is very low in water-abundant regions. The water abundant regions are the eastern Indo-Gangetic plains, covering most parts of Uttar Pradesh, the entire Bihar, and alluvial plains of West Bengal and Assam. These areas have high rainfall, very good aquifers, and perennial flows in streams and rivers, and large number of ponds and tanks. The water-scarce regions are those in peninsular India, underlain by hard rock aquifers with low to medium rainfall and high aridity; hilly areas receiving high rainfall (western Ghat, eastern Ghat, north eastern hilly areas, Himalayan mountain areas); western India underlain by hard rocks, sedimentary rocks and alluvium mostly having very low to low and medium rainfall; north western India, with low to medium rainfall, high aridity but underlain by alluvial aquifers.

The reasons for high cost of production of water in these regions are as follows. *First*: groundwater resources potential is very low in the hard rock areas of the south and western India. *Second*: they are heavily over-exploited in most parts of the south Indian peninsula, western India and most parts of alluvial north western India. Depletion of groundwater resulting in lowering of water levels, increase in cost of wells/bore wells, pumps and the reducing well yields increase the cost per unit of water pumped. *Third*: surface water resources are heavily over-appropriated in the basins of peninsular, western and north western India, barring the Godavari river basin in the South-east. Hence, water is not available in the downstream parts after the monsoon months. As a result, water has to be brought from distant places (reservoirs, lakes etc.) for meeting urban water needs. The degree of dependence on exogenous water increases with increasing size of the city, as the demand for water become too high for the local resources (groundwater and surface water) to cater to.

There are three important analyses which substantiate these arguments. *First*: in cities/towns and villages of states falling in hard rock areas viz., Andhra Pradesh, Karnataka and Tamil Nadu, the percentage contribution of groundwater to drinking water supply, in terms of number of households covered, is much smaller than that of surface water. Whereas in the villages and towns falling in the alluvial plains of Punjab, UP and Bihar, the groundwater contribution to the total drinking water supply, in terms of number of households covered, is much higher than that of surface water. It is quite possible that small towns falling in the hard rock areas still depend on bore wells for urban water supply, whereas the large cities depend purely on exogenous water from reservoirs.

*Second*: with passing of time, the water supply pattern changes from a single source to




a combination of sources (surface water and groundwater). This is indicated by the increase in percentage of population of towns covered by the combination of water supply sources among the group of cities falling in Class II category (see Figure 4) from 4.2 per cent in

1978-79 to 40.90 in 1999-00 (source: CPCB survey of 299 cities, 345 towns and 23 metros)[8]. This essentially implies that as time passes and also increase in population, the water utility will have to tap more than one source, as the existing sources either becomes defunct or inadequate to maintain the supply levels. It is generally found that in small towns falling in water-scarce regions of south India, water utilities shift from local streams, tanks and ponds to a combination of these sources and wells. This increases the cost of production of water as pumping costs would be added up.

*Third*: larger cities depend more on surface water resources, as indicated by the chart which shows that dependence on reservoir is very high for large cities (Figure 5, based on Mukherjee et al., 2010).

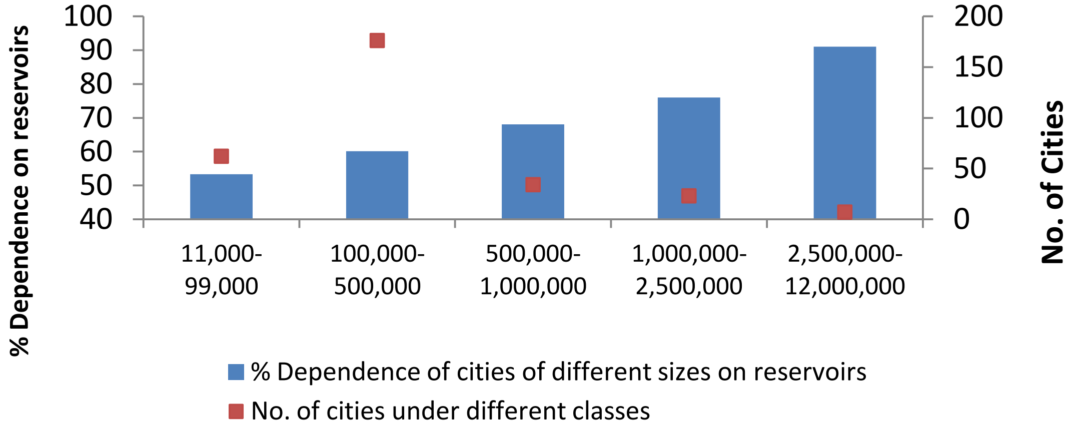
The cost of production and supply of water alone cannot be the consideration for choosing a particular source of water supply. How sustainably (across the season, and over reasonably long period of time), water supply can be provided is also an important consideration. In other words, a particular source of water supply might work out to be cheap, but might be able to meet only small fraction of the total water demand of a town or city. But, the second source, which has to supplement this first source, might work out to be prohibitively expenses. Hence, overall, the particular system might work out to be expensive.

Also, the chances for arranging alternative sources also become a consideration. A particular source might be very expensive. But, in situations where the possibility of arranging an alternative is absent, the costly systems will have to be resorted to.

Integrating the analysis presented in these figures, it could be reasonably argued that groundwater alone could be sustainable sources of the sole water supply in small towns (Class II and Class I excluding metros) in the water abundant regions of eastern Gangetic plains, after the local surface water sources are tapped. It could be the sole source of water supply in the alluvial Indo Gangetic plains, where surface water resources are limited. In very large cities, groundwater in conjunction with surface water from large reservoirs and lakes could be the sustainable sources of water supply.

Whereas groundwater could be one of the many sources of water for meeting urban water needs in small towns in the water-scarce regions of the south. Exogenous surface

**Figure 5: Degree of Dependence of Cities on Reservoirs (301 Cities/Towns)**




8 While at least some of the small towns (Class II) of the 70s might have become Class I towns in 20 years, the chances of smaller towns becoming large enough to fall in this category are less, as small towns have been experiencing very low growth rate. Hence, we can safely conclude that the situation with regard to water sources at different points of time is more or less of the same set of towns.

water would become the major source of sustainable water supply in large cities of the south, which can be supplemented by local groundwater.

### 7.1.1 Physical Feasibility of Using Groundwater for Urban Water Supply

The physical feasibility of using local groundwater for water supply is a function of the area from which groundwater can be tapped, the total population size in the urban area and the per capita water demand. Within the same geological setting, when the area of the administrative unit increases, the groundwater potential increases, whereas when the population living within this area increases, the demand increases. Hence, the extent to which the local groundwater can meet the urban water demand would be a function of the groundwater availability per unit area (or "groundwater richness") and the population density. Here, while estimating the groundwater availability, only the renewable groundwater resources is considered.

Groundwater richness is a function of the formation characteristics, i.e., unconsolidated, semi consolidated or hard rock; and the quantum of rainfall. The characteristics such as the rainfall infiltration rates and the specific yield vary widely from unconsolidated to semi consolidated to consolidated formations. Values of both the parameters start decreasing from unconsolidated to consolidated formations (see Table 8). Unconsolidated formations are generally groundwater rich owing to high specific yield and rainfall infiltration factor. Semi consolidated formations (semi consolidated limestone, shale and sandstone) have moderate groundwater potential and consolidated formations (basalt and crystalline rocks) have very poor groundwater potential. Hilly aquifers have almost zero groundwater potential. But, it is important to remember that high rainfall infiltration factor does not guarantee high recharge, as the specific yield of the aquifer and the empty storage space in the formation would ultimately determine the actual amount of infiltration of the precipitation.

Table 8: Showing Factors Influencing Groundwater Richness

| Sr. No | Formation | Specific Yield | Rainfall Infiltration Factor |
|---|---|---|---|
| 1 | Unconsolidated formations | 0.04-0.20 | 0.08-0.25 |
| 2 | Semi consolidated formations | | |
| a. | Shale, sandstone | 0.01-0.15 | 0.03-0.14 |
| b. | Lime stone | 0.01-0.03 | 0.06-0.07 |
| c. | Laterite | 0.01-0.04 | 0.05-0.08 |
| 3 | Consolidated Formations | | |
| a. | Granite, gneisss, schists | 0.01-0.04 | 0.03-0.11 |
| b. | Basaltic rocks | 0.01-0.025 | 0.06-0.12 |
| c. | Quartzite | 0.015-0.03 | 0.06-0.08 |
| d. | Massive crystalline rocks | 0.002-0.015 | 0.01-0.08 |

Source: GOI, 2005 as cited in Chatterjee and Purohit (2009)

The extent to which the urban water demand in a town can be met by groundwater ($X$) (%) can be estimated by the mathematical formulation as:

$$X = \frac{\mu * \Delta}{\emptyset * \mathrm{p}} \dots\dots\dots\dots\dots\dots\dots. (1)$$

Here, $\Delta$ is the groundwater richness in terms of $m^3$/sq. km per annum; and $\emptyset$ is the population density of the urban area in no. of persons per sq. km; p is the estimated per capita water demand in $m^3$ per capita per annum; and $\mu$ is the distribution (conveyance) efficiency in percentage. The population density of the urban area can be obtained from the total geographical area and the total population.

The groundwater richness figures for urban areas falling in different geological settings are given in Table 9A.

Table 9A: Groundwater Richness of Different Geological Formations in India

| Sr. No | Nature of Formation | "Groundwater richness" (ha-m per sq. km) range |
|---|---|---|
| 1 | Extensive alluvium (unconsolidated) | 42.50 |
| 2 | Sedimentary sandstone, limestone (semi-consolidated)-alluvial deposits | 4.67 |
| 3 | Consolidated formation (basalt & crystalline hard rock) | 13.20 |
| 4 | Hilly aquifers | |
| 5 | Thar desert region (Jaisalmer, Churu, Balmer, Bikaner, Ganganagar, Hanumangarh) | 0.890 |

Source: based on data provided in GOI, 2005

Note: for estimating "groundwater richness", the renewable groundwater availability data for six states (Andhra Pradesh, Karnataka and Tamil Nadu) were used for consolidated formations; four states (Punjab, UP and Bihar) for unconsolidated formation and one state (Rajasthan except the Thar desert) for semi consolidated formation. Also, data for four districts in TN were excluded from calculations as they showed zero renewable groundwater availability.

The equation and the figures provided in Table 9A show that in hard rock areas with high population density, the extent to which groundwater can contribute to urban water supplies will be insignificant. Whereas in urban areas underlain by extensive and rich alluvium, groundwater can meet a significant portion of the total urban water demand even if the population density of the town/city is high. Figure 6 provide the groundwater recharge (m) in different districts of India (source: GOI, 2005, as cited in Chatterjee and Purohit, 2009).

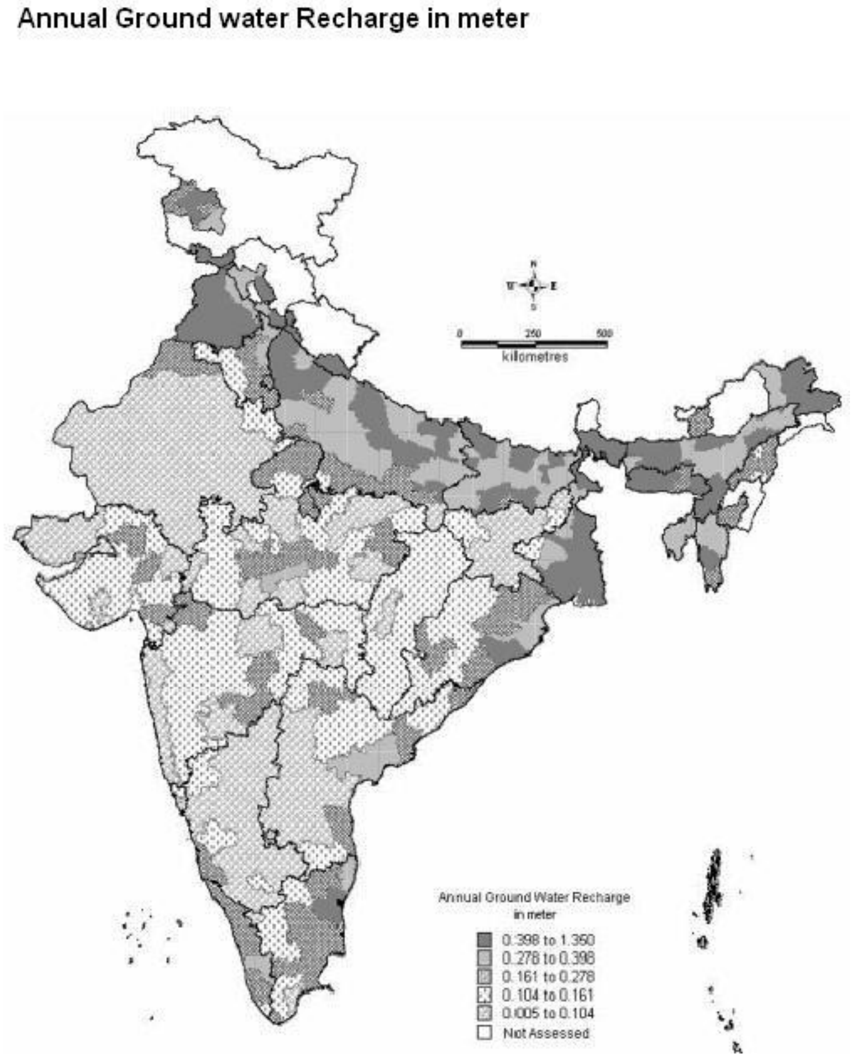



Figure 6: Annual Groundwater Recharge (m) in Different Districts of India

### 7.1.2 The Potential of Local Surface water Resources for Meeting Urban Water Demands

The extent to which surface water resources of a locality can be tapped for meeting urban water needs of that locality depends on several factors: 1] the total amount of surface water resources available from the catchments in the form of stream flows or natural storages in the local tanks, ponds and lakes; 2] the utilizable fraction of the water resources; 3] the extent to which these water resources are already tapped for various other uses, and therefore the uncommitted flows that can be made available from the catchments for future use; and, 4] the quality of the available water. As regards the first one, it is a function of the rainfall in the catchment, its intensity and pattern of occurrence; the catchment characteristics such as the land-use; the soil characteristics and soil moisture regime.

Increased area occupied by crops and grass canopy in the catchment would reduce the runoff rates as more water would infiltrate through the top soil by virtue of the pores and fissures in it created by the plants. Also, a good portion of the available runoff would be captured *in situ* in the farms where crops are grown.

All other factors remaining the same, the soil moisture regime is a function of the climate. If the area is characterized by high temperature, wind speed and low humidity (resulting in high PE), the available soil moisture would evaporate fast from the soil. Or, if the area is characterized by high temperature, low humidity and high wind speed and covered by crops for larger part of the rainy season (leading to high PET), the soil moisture will be depleted by crop evapo-transpiration. Conversely, if the area has low evaporation or potential evapo-transpiration, then the rate of soil moisture depletion would be slow and as a result, the top soil would get saturated quickly, resulting in the entire rainfall being converted into runoff. The utilizable fraction of the water resources in the catchment depends on several complex factors, such as the flow topography and the flow regimes. If the peak floods constitute a large share of the total annual stream-flows (like in the case of Brahmaputra sub-basin of Ganges and west flowing rivers south of Tapi), then the utilizable portion of the stream-flows would be less from an economic point of view. Similarly, if the streams do not have high embankments, the utilizable portion would further reduce as the number of feasible sites for creating storage reservoirs and diversion systems would be considerably less.

In India, the utilizable surface water resources per unit area vary from basin to basin depending on variations in the hydrological characteristics mentioned above (GOI, 1999; Kumar *et al.*, 2006 and 2008). The figures, worked out on the basis of the dependable basin yield and other considerations, are given in Table 9B. It provides data of utilizable surface water resources for 18 major river systems. On the basis of the area of catchments available for tapping for a particular urban area, and the utilizable surface runoff (derived from the dependable yield of the basin), the total surface water resources, which can be tapped for use, can be estimated. However, as mentioned early, the amount of water from the catchment or basin already committed for other uses and appropriated through reservoirs and diversion systems, need to be factored out in the calculations. In many river basins, these committed flows are very high. Some examples are the Ganges, Sabarmati, Banas, Cauvery, Krishna, Pennar, the west flowing rivers north of Tapi in Saurashtra and Kachchh. On the other hand, a large share of the flows in Brahmaputra-Meghna river system in the north east, and Godavari in the south remain untapped.

But, it is to be kept in mind that the actual utilizable surface runoff in a basin can vary widely across the basin due to the large differences encountered in rainfall and reference evaporation ($ET_0$) across the basins in India (Kumar *et al.*, 2006; 2008). In most of India' river basins, the rainfall is comparatively higher in the upper catchments, and $ET_0$ lower. Hence, the planners should make their own judgements while deciding the probable runoff rates, depending on the location of the catchment under consideration vis-à-vis the basin drainage area. For lower parts of the basin, the value should be lower than the average runoff rate figures provided in Table 9B, whereas for upper catchments, the value could be higher than the average rates.

Table 9B: Annual Flow, Utilizable Surface Water and Average Runoff Rates

| Sr. No | Name of the river basin | Catchment area in India (sq. km) | Average Annual Surface water potential ($km^3$) | Utilizable surface water resources ($km^3$) | Average Runoff Rates (m) |
|---|---|---|---|---|---|
| 1 | Indus | 321289 | 73.31 | 46 | 0.143 |
| 2 | Ganga- | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | Brahmaputra-Meghna | | | | |
| | Ganges | 861452 | 525.02 | 250 | 0.290 |
| | Brahmaputra-Meghna | 236136 | 585.6 | 24 | 0.102 |
| 3 | Godavari | 312812 | 110.54 | 76.3 | 0.244 |
| 4 | Krishna | 258948 | 78.12 | 58 | 0.224 |
| 5 | Cauvery | 81155 | 21.36 | 19 | 0.234 |
| 6 | Subarnarekha | 29196 | 12.37 | 6.81 | 0.233 |
| 7 | Brahmani and Baitarani | 51822 | 28.48 | 18.3 | 0.353 |
| 8 | Mahanadi | 141589 | 66.88 | 49.99 | 0.353 |
| 9 | Pennar | 55213 | 6.32 | 6.86 | 0.124 |
| 10 | Mahi | 34842 | 11.02 | 3.1 | 0.089 |
| 11 | Sabarmati | 21674 | 3.81 | 1.93 | 0.089 |
| 12 | Narmada | 98796 | 45.64 | 34.5 | 0.349 |
| 13 | Tapi | 65145 | 14.88 | 14.5 | 0.223 |
| 14 | WFR south of Tapi up to Tadri | 55940 | 87.41 | 11.94 | 0.213 |
| 15 | WFR south of Tadri up to Kanyakumari | 56177 | 113.53 | 24.27 | 0.432 |
| 16 | EFR between Mahanadi & Pennar | 86643 | 22.52 | 13.11 | 0.151 |
| 17 | EFR between Pennar & Kanyakumari | 100139 | 16.46 | 16.73 | 0.167 |
| 18 | WFR of Kachchh & Saurashtra including Luni | 321851 | 15.1 | 14.98 | 0.047 |

Source: based on data provided in GOI, 1999: Table 3.6

The annual utilizable yield of a catchment (in MCM) having an area of $A$ (sq. km) and average runoff rate $r$ (m) can be estimated as:

Annual utilizable yield of a catchment $= A * r$ …........... (1)

The extent to which the urban water demand in a town can be met by local surface water (Y) (%) can be estimated by the mathematical formulation as:

$$Y = \frac{A * r * \mu}{p * P} \quad \text{.......................................................... (2)}$$

Here, $p$ is the estimated per capita water demand in $m^3$ per annum; $\mu$ is the efficiency of conveyance of water from source to the demand site; and $P$ is the total urban population in million.

### 7.1.3 Water Supply Sources for Integrated Urban Water Management

The first step is to list the various water supply options physically feasible and economically viable for different typologies, as it is quite likely that in the same typology, more than one option would be viable from both fronts. The technological option for water supply under various typologies based is given in Table 9C. Table 9c provides a list of options for each typology, and does not mean that one can fully depend on one of these options. It only means that the particular option could also contribute to urban water supply provisions, or in other words, it does not integrate environmental sustainability considerations. Whether this option could actually become a viable source for a given town can be decided on the basis of several criteria used in combination. They are: cost of supply; supply potential; scope for decentralization; and the O & M requirements. The manner in which these criteria will have to be used for selecting a sustainable water supply source for a town is shown in the Table 9D.

Table 9C: Water supply Options for different urban typologies

| Typology | Water Supply Options | | | | | |
|---|---|---|---|---|---|---|
| | Lifting from local river | Groundwater abstraction | Local lake/pond/ tank | Surface water from reservoirs | Surface water import | RHWS/ Desalination |
| 1: North Gujarat, SW Punjab & Haryana | | XXX | | | XXX | |
| 2: Western UP and Punjab | | XXX | | | | |
| 3: Eastern UP & Bihar | XXX | XXX | | | | |
| 4: Coastal Orissa and WB | | XXX | XXX | | | |
| 5: North Western MP | | XXX | XXX | XXX | | |
| 6: Tripura, Mizoram | | | XXX | XXX | | |
| 7: Meghalaya, parts of Mizoram, Manipur, Nagaland parts eastern Himalaya | | | | | | RWHS |
| 8: Thar desert | | | | | XXX | XXX |
| 9: Andhra Pradesh, TN and Maharashtra, Chattisgarh and Jharkhand parts | | XXX | XXX | XXX | | XXX |
| 10: Orissa | XXX | XXX | XXX | | | |
| 11: Karnataka | | XXX | XXX | | XXX | XXX |
| 12: NE region | | | | | | RWHS |
| 13: Parts of Karnataka & Maharashtra and Saurashtra plains | | XXX | XXX | | XXX | |
| 14: Vindhyan / Satpura Hills MP | XXX | | XXX | XXX | | |
| 15: Kerala coast, Goa coast and Coastal Maharashtra | XXX | XXX | XXX | XXX | | |
| 16: Saurashtra coast | | | | XXX | | XXX |

Source: based on authors' own analysis

Table 9D: Technical, Economic and Institutional Criteria for Choosing Viable Water Supply Options for IUWM

<table>
<tr><td rowspan="4">Criteria for choosing a technology option for water supply improvement</td><td colspan="6">Overall physical condition w. r. to water availability and socio-economic status</td></tr>
<tr><td colspan="3">Water-scarce</td><td colspan="3">Water rich</td></tr>
<tr><td>City including metro</td><td colspan="2">Small town</td><td>City including metro</td><td colspan="2">Small town</td></tr>
<tr><td>Urbanized</td><td>Urbanized</td><td>Less urbanized</td><td>Urbanized</td><td>Urbanized</td><td>Less urbanized</td></tr>
<tr><td>Unit cost of production</td><td style="background:#d9d9d9"></td><td style="background:#d9d9d9"></td><td style="background:#d9d9d9"></td><td style="background:#d9d9d9"></td><td style="background:#d9d9d9"></td><td style="background:#d9d9d9"></td></tr>
<tr><td>Supply Capacity</td><td style="background:#d9d9d9"></td><td style="background:#d9d9d9"></td><td style="background:#d9d9d9"></td><td style="background:#d9d9d9"></td><td></td><td></td></tr>
<tr><td>Possibility for decentralization</td><td></td><td></td><td style="background:#d9d9d9"></td><td></td><td></td><td style="background:#d9d9d9"></td></tr>
<tr><td>Need for O & M</td><td></td><td></td><td style="background:#d9d9d9"></td><td></td><td></td><td style="background:#d9d9d9"></td></tr>
</table>

Source: based on authors' own analysis

Notes: 1] shaded cell indicates that a particular criterion is relevant; 2] Any city with a population more than 2 lac people is considered as a city. The rest are considered as small towns.

Urbanized towns and cities are those having high level of literacy, good number of qualified professional, and urban good infrastructure (schools, roads, transport facilities, buildings), and characterized by high economic outputs. Less urbanized here refers to cities/towns which have low level of education, poor infrastructure, and low income and also the water utilities will find hard to engage adequate number of well-qualified professions

## 7.2 Integrating the Physical Systems to Ensure High Reliability of Water Supplies

Many urban areas are endowed with multiple sources of water (like surface water in tanks and ponds, stream flows and groundwater) that are capable of augmenting the supplies. When these systems are often hydraulically linked, integrated planning and development is crucial for sustainably water supplies (Mitchell, 1990). For instance, exploitation of groundwater from shallow aquifers for municipal supplies in urban areas which have freshwater lakes, should consider the hydraulic interaction between the lake systems and the groundwater. Hence, protecting the lake system would require reducing the groundwater draft and maintaining the water table at a level if the groundwater outflows contribute to lake inflows. Whereas in situations where lake water contribute to groundwater recharge, sustainable development of groundwater for water supplies should consider the infiltration from the lake or tank bed.

In peninsular India, many cities and towns are surrounded by lakes and ponds. However, the reliability of water supplies from these ponds is low due to high variability in rainfall and runoff these regions experience. So, in good years, water could be imported from donor basins in almost the same quantity as that is imported during normal and bad years, and the surplus amount after meeting the city demand, which is equal to the replenishments in local aquifers during the good year, can be stored in these surface structures. This will be wise from an environmental and ecological perspective as the basin would be open. This is applicable to basins such as Krishna, and Cauvery that are "water scarce".

The pumping of groundwater in and around these structures would induce greater recharge of water from these ponds and lakes to the shallow aquifers so as to increase the storage space in the lakes/tanks/ponds. This would act as the buffer for bad years. Hence in bad years, the dependence on exogenous sources could reduce. This could help avert crisis that is likely to arise out of export of water from the donor basins when scarcity situation prevails in the basin.

Lack of integration of resource use can sometimes result in serious environmental problems (Kumar, 2010) like what was observed in Jodhpur. Jodhpur used to draw water from several of the tanks surrounding the city. But, with water being made available from the Indira Gandhi Nehar Yojna (IGNP), the municipal corporation has now stopped water from these tanks. The water, which remains in these tanks throughout the year, induces a lot of recharge to the shallow aquifer underlying the city. As a result, water levels have come up. The rise water level is resulting in the flooding of the basements of houses in the city. The most ideal choice would have been integration of the ponds with the water transfer system of IGNP for the city. As the tanks get dried up with diversion of water for municipal use, the imported water could be used to fill them up, and water can be drawn these tanks.

## 7.3 Storm Water Management Systems and Policies

### 7.3.1 Introduction

IUSM is a management concept that has evolved in the west over the last 20 to 30 years largely in response to the knowledge that the rapid conveyance of urban storm water led to the environmental degradation of receiving waterways (Wong and Eadie, 2000). It has more recently been influenced by the growing interest in "integrated urban water management" and the idea that urban storm water could provide a valuable water resource. Overall, it is a concept concerned with enabling more sustainable management of urban storm water environments. However, the significance of IUSM does vary between places attracting more attention in places such as Australia, New Zealand, and many parts of the United States because the storm water drainage network is typically separate system from the wastewater network, unlike many places across Europe. In India, the new urban planning includes separation of drainage network from the sewer network.

Separating out the storm water from the wastewater is important on two counts: 1] it prevents the dilution of wastewater, thereby help in increasing the energy recovery efficiency in wastewater treatment processes high; 2] it helps in preventing contamination of storm water, which is an important resource in water-scarce regions.

- Flood reduction--minimizing peak storm water discharges from urban catchments
- Pollution minimization--by preventing, collecting, and/ or managing pollution loads
- Storm water retention--harvesting and beneficial reuse of rainwater and storm water runoff within or near the urban catchment
- Urban landscape improvement--showing rather than hiding water by functionally incorporating storm water into urban streetscapes and green areas

- Reduction of drainage investments--innovative integration of storm water systems into the urban environment for reducing the cost of infrastructure.

In Thailand for instance, roof water tanks are used to protect the peak floods, thereby reducing the cost of the flood control infrastructure. In Sydney in Australia, the roof water tanks were found to help improve the urban water supplies, while reducing urban floods.

These synergetic effects are difficult to achieve in storm water management in practical situations always. The reason being: there is very low incidence of cities which experience problems of frequent flooding problems facing physical shortage of water, and vice versa; 2] issues of pollution of water bodies are least likely in places which experience flooding. Because of these features, when flood control benefits of storm water management become high, the benefits of water conservation become low, as the cost of alternatives for producing & supplying domestic water supplies would be much low. In situations where the economic benefits of creating new water sources through storm water conservation are high (in high rainfall hilly areas) due to high cost of supplying water through alternative ways, the flood control and environmental management benefits are very low.

There were three different stages in the discourse on urban storm water management: 1] storm water quantity discourse; 2] storm water quality discourse; and 3] storm water sustainability discourse.

Storm water management systems are a key to protecting and enhancing the urban environment. The need for storm water management systems grows along with urban development. This is because, the proportion of built up area to the total geographical area of the urban centre increases, with congestion of space increasing the storm water generation potential of the urban catchments.

### 7.3.2 Stormwater Management Measures

Storm water management measures can be structural and non-structural. Non-structural storm water control measures include a wide range of actions that can reduce the volume of runoff and pollutants from a new development. Examples include the use of products that contain less pollutants; improved urban design, for example, of new developments that have fewer hard surfaces; the disconnection of downspouts from hard surfaces to instead connect with porous surfaces; the conservation of natural areas; and improved watershed and land use planning (Source: National Academy of Sciences, 2008).

Structural storm water control measures are designed to reduce the volume and pollutants of small storms by the capture and reuse of storm water, the infiltration of storm water into porous surfaces, and the evaporation of storm water. Examples include rainwater harvesting systems that capture runoff from roofs in rain barrels, tanks, or cisterns; the use of permeable pavement; the creation of "infiltration trenches," into which storm water can seep or is piped; and the planting of rain gardens on both public and private lands (Source: National Academy of Sciences, 2008).

The management techniques can vary widely and can include facilities such as piping, retention ponds, wetlands, planting of drainage swales along the road side that capture and treat storm water; rain water gardens, roof-top gardens, cistern barrels, or pervious pavement. These efforts are intended to serve multiple purposes such as reducing the rate of runoff, improving the quality or cleanliness of the runoff, and recycling the water back into the groundwater systems, where the dependence on groundwater is heavy, and the resource is scarce.

### 7.3.3 Institutional Issues in Stormwater Management

Although the development of IUSM techniques flourished over the last decade in Australia, the administration of these approaches has not been widespread. Since the Storm Water Forum in 1993, there have been various evolving forms of State task forces, advisory bodies, and policy groups producing a series of recommendations and strategic policy reports. The most significant outcome of these groups was the recognition of the need for an integrated approach for the administration of urban storm water management between Sydney Water, local governments, and other relevant state agencies and community groups for sharing responsibility (McManus, 1996). In the context of Australia, it was also acknowledged that significant impediments to achieving an integrated approach to IUSM included: i] the current administrative arrangements; ii] inadequate funding allocated to urban storm water management at all levels of government; iii] fragmented organizational responsibilities; and, iv] an overall lack of legal accountability (CEPA, 1993; Sharpin, 1996).

In Indian context, "flood control" is within the purview of the irrigation department. The urban utilities do not count on the "flood control benefits" while investing in storm water drainage. Also, degradation of river water quality due to mixing with storm water is still not perceived as an environmental degradation problem. As a result, fund allocation to this programme is often inadequate, and is just sufficient to dispose of the storm water from the locality.

In the context of Australia, several scholars pointed out that the current organizational administration of urban storm water management is the most significant impediment to enabling the implementation of IUSM has been informed by experiential evidence from water managers working in the industry (Brown and Ball, 1999; Brown and Ryan, 2000; Brown, 2003). It has also been grounded by broader commentary that argues that when integrated environmental management approaches are superimposed onto conventional administrative regimes, there will inevitably be a number of administrative impediments. These typically include issues related to jurisdictional and institutional fragmentation resulting in overlapping and often undefined responsibilities between numerous organizations, followed by lack of organizational commitment to changing implementation practices (see, for example, Burby and May, 1998; Cortner and others, 1998; Margerum, 2001).

Increasingly, commentators highlight that the organizational administration of IUSM is yet the most challenging dimension to practical realization (such as Tyson and others, 1993; Geiger and Hofius, 1996; Lawrence and others, 1999; Brown, 2003). As argued by Marsalek and others (2001) and Brown (2003), they have not been the subject of systematic research with the explicit agenda of advancing knowledge on how to institutionalize IUSM.

The organizational administrative impediments to enabling the implementation practice of IUSM can be typified into the characteristics relating to technocratic power and expertise, values and leadership, and structure and jurisdiction (Brown, 2004). The technocratic structure of the administrative regime inherently gives emphasis to technical expertise and economic rationalism over an interdisciplinary alternative that values community participation in decision making and environmental sustainability. For instance, in India, communities do not pay for ecosystem services offered by urban lakes. Hence, the officials engaged in storm water management do not perceive any direct economic benefit arising out of storm water management interventions that would protect the lakes from contamination due to mixing up with urban storm water. The result is that they tend to support only those interventions by which they can derive urban flood control benefits which exceed the costs of the interventions. Consequently, the investments are only minimal covering the storm water drainage systems.

With sustainability necessitating a broader knowledge and skill base, this also challenges the traditional administrative domain of the established storm water engineering community. These engineers have been responsible for providing a level of service that communities have learned to expect in terms of reliability and quality of water resources, flood protection and recently, protection of the amenity of local waterways. This reorientation attracts the implication of sharing of expertise status and the potential redirection of scare resources elsewhere. Given this, it is clear that an administrative regime that promotes a learning environment facilitating multidirectional information exchange is required whereby the public and various disciplinary technical experts gain broader understanding of the totality of factors involved. This is likely to be essential in dismantling institutional barriers and creating relationships, while fostering community support where there are conflicting societal goals.

Scott, (1995) provides the analytical framework to explain the social practices (Table 10). There are three mutually dependent dimensions of institutions that enable or constrain institutionalized practice.

While some bureaucrats and politicians share the vision of sustainability, the impediment appears to be the lack of leadership among the executives in implementation. This combined with the limited parameters of decision-makers' knowledge and bureaucratic inability to deal with competing interests, together with the electoral demands faced by politicians, further entrenches the institutional inertia. The inability to transform means the technocratic/expert-driven approach to policy and devising solutions to water issues continue to be the norm.

Table 10: Analytical framework for Explaining Social Practices

| Dimension of Institution | Description | Explanatory Power |
|---|---|---|
| Cognitive | Shared meaning of the term | Expressed through technologies, planning processes, organizational structures, policies, laws etc |
| | Knowledge framework considered | |
| Normative (values) | Shared values & expectations | How values and expectations structure choices/organized actions |
| | Social actions considered appropriate for pursuing objectives | |
| Regulatory (administrative) | Rules and Sanctions | How practice is organized according to what are considered appropriate actions to pursue shared values |
| | Organizational forms | |

Source: Scot (1995)

### 7.3.4 Tools for Planning Stormwater Management

Estimating the urban runoff is crucial to designing systems for their collection and disposal. In the case of urban storm water, what is more important is the runoff intensity rather than the total quantum of runoff from the catchments, as the water, if get accumulated, can cause flooding of the low lying areas of the city/town. The important design consideration for urban storm water drains, therefore, is the runoff intensity.

High intensity rainfalls of short duration are peculiar of Indian monsoon and occur even in low rainfall areas (Pisharoty, 1990). Normally, the intensity of storm which occurs less frequently and for shorter duration will be of higher magnitude than those which occur more frequently and for longer time duration. Hence, the SWM systems will have to be designed for floods of very high return period.

The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. The runoff component of SWMM operates on a collection of sub-catchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each sub-catchment, and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprised of multiple time steps.

SWMM was first developed in 1971, and has since undergone several major upgrades since then. It continues to be widely used throughout the world for planning, analysis and design related to storm water runoff, combined sewers, sanitary sewers, and other drainage systems in urban areas, with many applications in non-urban areas as well. The current edition, SWMM 5, which runs under Windows, provides an integrated environment for editing study area input data, running hydrologic, hydraulic and water quality simulations, and viewing the results in a variety of formats. These include colour-coded drainage area and conveyance system maps, time series graphs and tables, profile plots, and statistical frequency analyses.

### 7.3.5 Capabilities and Application of SWMM Tool

SWMM accounts for various hydrologic processes that produce runoff from urban areas. These include: 1] time-varying rainfall; 2] evaporation of standing surface water; 3] snow accumulation and melting; 4] rainfall interception from depression storage; 5] infiltration of rainfall into unsaturated soil layers; 6] percolation of infiltrated water into groundwater layers; 7] interflow between groundwater and the drainage system; and 8] nonlinear reservoir routing of overland flow.

Spatial variability in all of these processes is achieved by dividing a study area into a collection of smaller, homogeneous sub-catchment areas, each containing its own fraction of pervious and impervious sub-areas. Overland flow can be routed between sub-areas, between sub-catchments, or between entry points of a drainage system.

SWMM also contains a flexible set of hydraulic modelling capabilities used to route runoff and external inflows through the drainage system network of pipes, channels, storage/treatment units and diversion structures. These include the ability to: handle drainage networks of unlimited size; use a wide variety of standard closed and open conduit shapes as well as natural channels; model special elements such as storage/treatment units, flow dividers, pumps, weirs, and orifices apply external flows and water quality inputs from surface runoff, groundwater interflow, rainfall-dependent infiltration/inflow, dry weather sanitary flow, and user-defined inflows; utilize either kinematic wave or full dynamic wave flow routing methods; model various flow regimes, such as backwater, surcharging, reverse flow, and surface ponding; apply user-defined dynamic control rules to simulate the operation of pumps, orifice openings, and weir crest levels.

In addition to modelling the generation and transport of runoff flows, SWMM can also estimate the production of pollutant loads associated with this runoff. The following processes can be modelled for any number of user-defined water quality constituents: dry-weather pollutant build-up over different land uses; pollutant wash off from specific land uses during storm events; direct contribution of rainfall deposition; reduction in dry-weather build-up due to street cleaning; reduction in wash-off load due to BMP; entry of dry weather sanitary flows and user-specified external inflows at any point in the drainage system; routing of water quality constituents through the drainage system; reduction in constituent concentration through treatment in storage units or by natural processes in pipes and channels.

Since its inception, SWMM has been used in thousands of sewer and storm water studies throughout the world. Typical applications include: design and sizing of drainage system components for flood control; sizing of detention facilities and their appurtenances for flood control and water quality protection; flood plain mapping of natural channel systems (SWMM 5 is a FEMA-approved model for NFPI studies); designing control strategies for minimizing combined sewer overflows; evaluating the impact of inflow and infiltration on sanitary sewer overflows; generating non-point source pollutant loadings for waste load allocation studies; evaluating the effectiveness of BMPs for reducing wet weather pollutant loadings.

### 7.3.6 Stormwater Runoff Recharge Using Rain Gardens

One of the ways to manage the storm water is to use the same for recharging the aquifers (Dussaillant *et al.*, 2005; National Academy of Sciences, 2008). This would improve the sustainability of water resources, water supplies, and also storm water collection systems and also wastewater management in semi arid regions, where the groundwater becomes a critical source of urban water supplies, whereas it may not be desirable in humid and sub-humid areas having high groundwater table.

A rain-garden for storm-water infiltration and bio-retention is a landscaped garden in a shallow depression (10–30 cm depth) of relatively small area that receives the storm water from a roof, parking lot or other impervious surface. The garden plants provide a biologically active root zone that maintains soil infiltration and porosity. Additionally, plant evapo-transpiration during inter-storm periods provides a higher available soil water storage capacity for the next rainfall event (Dussaillant *et al.*, 2005).

### 7.3.7 Model for Design and Evaluation of Rain Garden

Dussaillant *et al.* (2005) developed a model for design and evaluation of rain gardens for different climatic conditions. The model uses the following parameters for estimating the water balance in the rain garden surface depression: 1] the rainfall; 2] the rainfall "run on", which is determined by the ratio of the impervious area to the pervious area; 3] soil infiltration rate; and, 4] the runoff, which is generated when the average depth of the ponding exceeds the maximum pond depth.

$$\frac{dh_s}{dt}A = Q_{run-on} + Q_{rain} - Q_{infiltration} - Q_{runoff}$$

The soil infiltration rate is estimated using the Green and Ampt Infiltration equation, on the basis of the depth of ponding at the time of infiltration, the difference in initial and saturated soil moisture storage ($\theta_{sat} - \theta_{ini}$) and the capillary intake of water ($h_{wf}$).

The equation is:

$$\frac{dF(t)}{dt} = \left(1 + {}^{B}/_{F(t)}\right)$$

Here F is the cumulative infiltration, and t is time.

B is estimated as:

$$B = \lfloor h_{wf} + h_s(t) \rfloor \lfloor \theta_{sat} - \theta_{ini} \rfloor$$

The soil is modelled as three homogeneous layers where the percolation between them is assumed to be only gravity driven. Then the drainage $d(t)$ from a top layer to the one below is approximated (Rawls et al., 1993; van Genuchten *et al.*, 1980) as:

The drainage between layers is estimated using

$$d(t) = K_{sat} * k^{1/2}(1 - (1 - k^{\frac{1}{m}})^m)^2$$

Here, $k = \frac{(\theta - \theta_{res})}{(\theta_{sat} - \theta_{res})}$; and $m = 1 - {}^1/_n$

$K_{sat}$ is the saturated hydraulic conductivity of the soil which drains. The RECARGA model was benchmarked to the RECHARGE model (Dussaillant et al., 2004), with good results. Then it was used to model the impact on recharge of the same type of rain garden/bio-retention cell to three cities with differing climates: Madison, Wisconsin (humid); Santiago, Chile (semiarid Mediterranean); and Reno, Nevada (arid climate).

For the humid climate of Madison, modelling results show very high recharge rates in the rainy season, where a rain garden with an area of 10 to 20% of the contributing impervious area maximizes recharge. For the semiarid climate of Santiago, Chile, the optimum ratio was 10 to 20%, and for the arid climate of Reno, Nevada, USA, it was closer to 5%. Optimal values for garden to impervious area ratios would not present apparent problems for plant survival, as judged from simulation results.

The modelling shows that in arid climates, increasing the infiltration area will not help beyond a point in increasing the recharge through the rain garden. The reason for this is that the evapo-transpiration would become excessively high when the area increases whereas the inflow remains constant.

### 7.3.8 Good Stormwater Management Policies

Some good storm water management policies are those which:

- Encourage use of energy and water conservation practices such as strategic landscaping.
- Utilize Best Management Practices (BMPs) to reduce surface water runoff and control erosion especially during public and private construction projects.
- Encourage creative solutions to storm water disposal in future developments that utilize natural drainage and infiltration systems in conjunction with storm water piping in semi arid and arid areas that are underlain by alluvial strata

- Evaluate and encourage alternative strategies for parking and street design in new developments that seek to minimize surface runoff. This is applicable to all types of areas, more particularly undulating areas

- Encourage good land-use planning for new urban areas that do not disrupt the natural infiltration of rainwater in high potential (recharge) area such as outcrop areas of aquifers.

The management of storm water runoff need not occur in isolation of other urban environmental initiatives. The potential agencies for funding such a programme are: urban sewerage department; urban water supply department; irrigation & flood control department; department for conservation of wetlands. In addition, by integrating the management of storm water with the conservation of potable water, wetland conservation, sewerage disposal, flood control, it may be possible to widen the range of benefits received by the target population, and at the same time, increase the program's ability to impact the problem setting.

A programme evaluation framework[9] used to understand the inputs, process and outputs that characterize the storm water/water conservation programmes in each of the Cities of Vancouver and Toronto identified six areas of programme improvement.

They are:

i) Dedication of adequate resources for the programme,

ii) Implementation of complementary policies,

iii) Exploitation of opportunities for inter-departmental collaboration,

iv) Innovative programme promotion,

v) Facilitation of homeowner participation, and finally,

vi) Monitoring of programme performance over time and adoption of change.

One of the complimentary policies could be tax benefits for buildings which provide adequate pervious space for infiltration of water in the compounds. Levying additional tax to those constructing buildings in highly "sensitive areas" such as vegetated areas, and aquifer outcrops could be another policy measure.

The outcomes that could be expected as a result of these improvements include: reduced pressure on sewer system and drinking water supplies; lesser occurrences of basement flooding and combined sewer overflows; and increased homeowner awareness for the urban hydrological cycle.

### 7.3.9 Urban Stormwater Management for Different Typologies

The storm water management intervention for a particular urban area should take into account the following:

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9 The incorporation of policy instrument evaluation and community-based social marketing theory into this framework has helped to further inform and elaborate upon each program component, and to reveal a wide range of program 'strengths' and 'weaknesses'.

A] The potential of urban storm water flows for creating local floods

B] Criticality of the storm water in the urban hydrology in terms of quality and quantity; and

C] Geo-hydrological environment.

The first parameter, i.e., the potential of urban runoff for creating floods would depend on the hydrological regime; the topography; and existing land-use in the urban area. The second parameter, i. e, the criticality of the storm water in the urban hydrology in terms of quality and quantity, would depend on the water resource endowment in the urban area, against the urban water supply demands. If the available water resources from the catchment of streams, ponds & tanks, and sustainable yield from local aquifers in the urban area is adequate enough to cater to the urban water demands, then the type of treatment that should be in place will be different from what is to be done in cases where the available water resources in the urban areas is less than adequate to meet the urban water demands.

In the first case, the storm water should be managed in such a way that it does not cause floods or contaminate the good quality water. In the second case, the storm water should be used as a resource for augmenting the water supplies. This would reduce the pressure on exogenous water for meeting the urban water needs. Nevertheless, if the storm water is highly polluted with toxic substances, then the treatment of the same storm water for reuse may not be economically viable. Instead, the approach should be to safely dispose off into natural sinks, after sufficient treatment.

The storm water management interventions would also be determined by the groundwater condition. The storm water is used for recharging the aquifers under two instances. First: the storm water is to be treated and used for augmenting the existing source of water. In the second instance, water has to be retained near the source of its generation for preventing urban floods. But, the ability to do so would depend on the geo-hydrological environments. If water table is deep (deep dewatered zone) and the aquifer has got good storage potential (specific yield), then recharging would be technically feasible. If water table is shallow like in the eastern Gangetic plains of India), then the aquifer does not provide sufficient space for storage of water during monsoon as most of the area is already under flood conditions with very high water table. More importantly, if the groundwater is saline, then using the storm water for recharging the aquifer for preventing the floods is not desirable as this would lead to soil salinity over a long time period. Among the factors discussed above, hydrology, geology are captured in the typology. Hence, we have classified the towns/cities falling in each typology into three categories, viz., large cities with large built-up area; small towns with high built up area; and small towns with low built up area.

The storm water management interventions for urban areas falling in different typologies are provided in Table 11:

Table 11: Stormwater management interventions for different urban typologies

| Typology No | Types of Storm Water Management Interventions in | | |
|---|---|---|---|
| | Large Cities with large built up area* | Small towns with large built up area | Small towns with small built up area |
| 1 | Stormwater collection using UGDs, and pond recharge for recharge after detention | Stormwater collection using UGDs, and pond recharge after detention | Stormwater collection using UGDs, and pond recharge after detention storage |
| 2 | Stormwater collection and pond recharge | Storm water collection, and pond recharge | Stormwater collection and safe disposal in natural sink after pond detention |
| 3 | Stormwater collection, and safe disposal in streams after pond detention | Stormwater collection and safe disposal in streams after pond detention | Stormwater collection and safe disposal in streams after pond detention |
| | In flood prone areas, RWH tanks could be constructed | | |
| 4 | Rain Gardens; excess storm water collection and safe disposal in streams after pond detention | Rain Gardens; excess storm water collection and safe disposal in streams after pond detention | Stormwater collection and safe disposal in streams after pond detention |
| | In flood prone areas, RWH tanks could be constructed | | |
| 5 | Stormwater collection, pond detention and recharge through ponds | Stormwater collection, pond detention and recharge through ponds | Stormwater collection, pond detention and recharge through ponds |
| 6 | No large cities | Stormwater collection and safe disposal in streams after pond detention | Stormwater collection and safe disposal in streams after detention |
| 7 | No special actions will be needed, except collection & conveyance of storm water through UGDs, as the surface drainage will be extremely good in the hills | | |
| 8 | Storm water collection and storage in natural ponds/tanks after detention as aquifers are saline in the Thar desert | | |
| 9 | Runoff reduction measures, excess storm water | Runoff reduction measures; excess storm water collection, detention | Stormwater collection, detention ponds and surface storage |

| | | | |
|---|---|---|---|
| | collection, detention ponds and storage on surface | ponds and surface storage in tanks | |
| 10 | No large cities | Runoff reduction measures other than RWSTs; excess storm water collection, detention ponds and surface storage | Storm water collection, detention ponds and surface storage |
| 11 | Runoff reduction measures other than RWHS & RG; excess storm water collection, detention ponds, and surface storage | Runoff reduction measures other than RWHS & RG; excess storm water collection, detention ponds, and surface storage | Stormwater collection & conveyance using UGDs, detention ponds and surface storage |
| 12 | Roof rainwater collection tanks for domestic water supply; runoff from other built up area to be drained off naturally by virtue of the hilly topography | | |
| 13 | Stormwater to be collected and conveyed through UGDs, storage in detention ponds and storage in tanks | Stormwater to be collected in UGDs, and stored in detention ponds and surface storage in tanks | Stormwater to be collected in UGDs, and storage in detention ponds and surface storage in tanks |
| 14 | Collection and conveyance of storm water through UGDs, and drainage of water from the town will be through gravity | | |
| 15 | Stormwater collection & conveyance using UGDs, and disposal into ocean | | |
| 16 | Stormwater collection & conveyance using UGDs, and storage in garland canals for continuous recharge of coastal aquifers (for preventing intrusion of seawater) | | |

Source: based on authors' own analysis

Note: RWST stands for rain water storage tank

Highly urbanized cities and towns will have much larger proportion of their geographical area under buildings as compared to less urbanized small towns.

## 7.4 Using Urban Storm Water for Recharging and Storage

In situations where aquifers have good recharge potential, and the top soil is highly pervious, storm water and roof water is used to recharge the shallow aquifers. For instance, in the city of Perth, as most of the urban area is underlain by high quality unconfined aquifer of Bassendean sand, it is normal practice to use this source for garden watering during the long hot summers. At the same time, the aquifer readily accepts roof runoff to shallow sock pits; acts to accept and to polish septic tank effluent and receives the majority of road runoff via infiltration swales and small wetlands. The consequences of this use of the aquifer in Perth is a reduced demand for reticulated water, a reduced cost in storm water drainage, and a reduced cost in necessary sewerage provision.

The storm water should, first, be allowed to infiltrate naturally into the soil, and then groundwater. The excess storm water can be kept in detention ponds. This water can then be used to recharge the aquifers using artificial recharge techniques.

This same approach is used on Long Island NY (USA) where storm water infiltrates through the shallow glacial outwash sands and gravels to recharge the deep Magothy Beds which provide the whole water supply to over 10 million people. Again, around the southern counties which fringe Los Angeles and around the Bay area of San Francisco, groundwater infiltration basins treat and recharge the hill wash sands and gravel which provide both storage and distribution of water resources to another 10 million people at small engineering costs. Such systems are common throughout the US. The condition for improved viability of this system of recharging the aquifer is the good storage space in the aquifer; and low depth to groundwater table as all these characteristics would reduce the cost of the system. The effectiveness of this system in reducing urban floods depends on the total roof area available against the total urban area. The cost would reduce if the pattern of rainfall is even, and rainfall is distributed over long time periods.

In the Indian context, study from four locations (Jaipur, Indore, and two locations in New Delhi) that fall under semi arid to arid climates with erratic rainfall has shown that recharge of roof water using recharge tube wells is prohibitively expensive. The cost ranged from \$ 0.15/$m^3$ to \$ 0.66/$m^3$. This high cost was due to the facts that the total amount of rainfall is low to medium and the same occurs during very short span of time, and the adverse geo-hydrological conditions that exist (Kumar, 2004: pp49).

Earlier analysis by Kumar (2004) showed that RWHS offer very limited scope, and is not physically and economically feasible for low to medium rainfall areas. Separate analysis is done for high rainfall hilly areas, where RWHS is practiced traditionally. The cost of Roof Water Tanks for rainfall varying from 2000mm to 3000mm for the north eastern hill region and Western Ghats is provided in Table 12. The cost calculations consider a life of 40 years for the system; and a discount rate of 6 per cent. The other assumptions made for estimating the unit cost of water storage through roof water tanks are given below the table.

Table 12: Unit Cost of Production of Water through RWHS in High Rainfall Areas

| Roof Catchme | Storage Capacity Required for Different Rainfall Regimes | Cost per Cubic Metre of Water Harvested (Rs/$m^3$) |
|---|---|---|

| nt Area ($m^2$) | 2000 mm | 2500 mm | 3000mm | 2000 mm | 2500 mm | 3000 mm |
|---|---|---|---|---|---|---|
| 40 | 42 | 54 | 52.5 | 70.22 | 69.2 | 56.1 |
| 50 | 51 | 65.75 | 75 | 65.38 | 67.4 | 61.3 |
| 60 | 60 | 77.5 | 97.5 | 61.31 | 63.4 | 66.4 |
| 80 | 75 | 97.5 | 123.75 | 57.48 | 59.8 | 57.5 |
| 100 | 90 | 117.5 | 150 | 55.18 | 55.0 | 52.9 |
| 120 | 90 | 120 | 157.5 | 45.98 | 44.6 | 46.3 |
| 150 | 105 | 141.25 | 187.5 | 42.91 | 39.9 | 41.8 |

Source: the authors' own analysis

Note: 1] It was assumed that the families having roof area of 40 $m^2$ would draw 60lpcd of water a day during times of inflow; the withdrawal would grow gradually to 100lpcd for 60 $m^2$; those with 80 $m^2$ roof area would draw 150lpcd of water; 100$m^2$ would draw 200lpcd of water; 120 $m^2$ would draw 300lpcd and 150 $m^2$ would draw 400lpcd of water.

2] It was further assumed that the cost of the underground tank of RWHS would reduce with increasing size from Rs. 1600/$m^3$ (US$ 320) for a 37.5 $m^3$ tank to Rs. 1200/$m^3$ for a 175$m^3$ plus capacity tank, and with that a minor economy of scale could be obtained with large-sized roof water tanks.

The above table shows that the unit cost is lower for RWHS with larger roof catchments, while the total amount harvested would be higher. It also shows that the unit cost reduces drastically when the households increase the daily withdrawal in proportion to the greater inflows available from the larger catchments. It also shows that the unit cost reduces with increase in number of days of withdrawal, which was assumed to be a function of increase in number of rainy days, and therefore days of inflow into the tank.

As there is a paucity of natural water storage and sparse population in such regions, the cost of provision of water supply through conventional systems would work out to be prohibitively high due to high cost of infrastructure for water conveyance and distribution and cost of energy used for lifting water. Under such a scenario, investment in RWHS can be justified if its unit cost works out to be less than the cost of provision of water through long distance pipelines. After Kumar (2004), the unit cost of water supply through conventional pipeline schemes depends heavily on the amount of lift. To meet the shortfall, government can invest in the cheapest of the alternatives. However, a little more work on these needs to be done.

7.4.1 Mathematical Formulation for Working out the Cost of RWHS

The total amount of water that can be harvested (V) in $m^3$=

$V = \propto * \Delta * \mu$ ........................... (1)

Here, $\propto$ is the roof area in $m^2$; $\Delta$ is the total annual rainfall in metres; and $\mu$ is the runoff coefficient for the type of roof that exists. The runoff coefficients for different types of roof are given in Table 13.

Table 13: Runoff Coefficient for Different Roof Types

| Type of Roof | Runoff Coefficient |
|---|---|
| Galvanised Iron Sheet | 0.90 |
| Asbestos Sheet | 0.80 |
| Tiled Roof | 0.75 |
| Concrete Roof | 0.70 |

Source: Manual on Construction and Maintenance of Household Based Rooftop Water Harvesting Systems, Report prepared by AFPRO (Action for Food Production) for UNICEF

Now, the cost per cubic metre of water would depend on the type of material used for construction of the tank, the type of geological formation that exists in the area in question and the actual storage capacity required to store the runoff generated. The actual storage capacity is the most complex part of the planning question. For a given storage capacity provided, the effective storage increases with the number of days of inflow during which demands are met from the storage. We have considered the total number of days of water withdrawal from tank during times of inflow to be equal to the total number of rainy days, and this (withdrawal during times of inflow) was considered only for locations which have high rainfall and larger number of rainy days (above 60 rainy days). Hence, for areas having low rainfall, the roof water tank is assumed to function as a storage system for monsoon flows to be used in winter and summer, and not as a storage-cum-diversion system. As a result, in such cases, the effective storage and storage capacity would be the same. While the cost of the system depends on the storage capacity provided, the cost per unit volume of storage depends on the effective storage.

The storage capacity required to storage a volume of as:

$$V_{tank} = \propto * \Delta * \mu - \delta * \cap \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

The unit cost of collection of water through RWHS $C_{roof-tank}$ (Rs/m$^3$) can be estimated as

$$C_{roof-tank} = \frac{1600\,\{\alpha * \Delta * \mu - \delta * \cap\}}{V} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Here, $\delta$ is the daily water demand in m$^3$ of a family/housing stock implementing RWHS; $\cap$ is the number of annual rainy days in the place under consideration. The empirical value of 1600 is taken as the cost of creating one cubic metre of underground storage system. However, this value can change depending on the local specific situation.

## 7.5 Desalination of Seawater and Saline Groundwater

There is absolute scarcity of good quality water in the coastal areas of many regions in India which receive low to medium rainfalls and which are underlain by hard rock geology, except the coastal strip. Groundwater is the only source of water in these regions. The cities/towns in these regions are facing acute water shortage. Desalination technology can be used to create freshwater supplies in these regions for basic survival needs such as drinking and cooking. The level of Total Dissolved Solids (TDS) in groundwater is higher than 5,000 ppm in these coastal belts, but does not exceed 10,000 ppm. Therefore, the process of Reverse Osmosis (RO) using membrane technology is most ideal for desalination in the area. The cost of desalination using Reverse Osmosis is given in Table 14.

Table 14: Capital Cost and O & M Cost of Desalination Plant by Installation Capacity using Reverse Osmosis

| Capacity of Desalination Plant ($m^3$ per Day) | Cost of Plant (Rs. In Lac) | Cost of O and M/ Year (Rs. in Lac) | Cost per $m^3$ of Water |
|---|---|---|---|
| 10 | 6.0 to 10.0 | 1.0- 2.0 | 61.80-105.60 |
| 20 | 8.0-11.00 | 2.0- 2.6 | 50.30-65.20 |
| 30 | 9.0-14.20 | 2.6- 3.40 | 40.90-56.60 |
| 50 | 16.0-27.20 | 3.6- 6.0 | 38.10.61.70 |
| 100 | 20.0-41.30 | 7.0- 11.0 | 30.60-53.00 |

Source: Shah *et al.* 1997 and authors' own analysis

The figures of capital and O & M cost for plants of various size were obtained from Shah et al. 1997. In order to estimate the cost of production of unit volume of water through RO, the following assumptions were made. 1. The member would cost nearly 30 per cent of the plant cost and that it has to be replaced once in every 3-4 years. The life of the system was assumed to be 10 years, and therefore the membrane will have to be replaced twice during the lifetime of the RO plant. A discount rate of 8 per cent was assumed for annualizing the initial investment towards plant installation. From the table, it can be seen that the cost per cubic metre of water drops gradually as the size of the plant increases, and the volume of production also increases proportionally. Therefore, the economy lies in selecting the optimum sized plant and operating it at the full potential. Selection of an over-sized plant would increase both the capital cost and the cost of replacement of membrane.

A desalination plant of 100$m^3$/day capacity, if run round the clock, will be sufficient to provide freshwater to a population of 10,000 people, at a rate of 10 litres per capita per day. If we go for decentralised plants of smaller capacities, a total of 20 plants of 100 $m^3$ per day capacity would be sufficient to cover the entire coastal area of Saurashtra and Kachchh with a total coverage of 2,00,000 people. The total capital investment required for this will be Rs.8 crore. The operation and maintenance cost will be nearly Rs.2.2 crore per annum. The cost of freshwater supplied from a desalination plant would be Rs.45 per thousand litres.

Research by CSMRI, Bhavnagar showed that if the salinity of the raw water is below 6000 ppm, the Reverse Osmosis process of desalination will be more cost effective. The cost of installation of the plant with a capacity of 10$m^3$/ day works out to be Rs. 180000 to Rs.250000. The electricity required for running the plant is 50 kWh for 10 $m^3$ of water. The annual operation cost therefore works out to be Rs.36500 (the cost of electricity is taken as Rs.2/kWh). The cost of one cubic metre (1000 litres) of water produced from the plant would be Rs.17-20 (IRMA/UNICEF, 2001).

Again, their research shows that if the salinity level of the raw water is below 5000 ppm than Reverse Osmosis technique. The cost of installation of a desalination plant using electro-dialysis, the technique called electro-dialysis can be used for desalination. It is far less expensive and having a capacity of 10 $m^3$ would be in the range of Rs.1-1.5 lac. Electricity consumption for operation of the plant is much less in comparison to Reverse Osmosis, and is 1 kWh for every one kilogram of dissolved salt removed from the raw water. Therefore, if the salinity level of the raw water is 5000 ppm, the electricity required for running the plant would be around 0.05 kWh per day for a plant having installed capacity of 10 $m^3$ per day. The cost of producing water would be in the range of 3-6 rupees per thousand litre of water, if the salinity levels of 3000-5000 ppm (IRMA/UNICEF, 2001).

Desalination plants using Reverse Osmosis technology had been installed in several parts of Saurashtra. Except in a large Heavy Chemicals unit, this process has not been found to be successful elsewhere[10]. One of the main reasons had been the lack of adequate operation and maintenance. In several instances, the plant had to be shut down, after the maintenance and repair contract was over. To ensure successful operation of a desalination plant, the following steps need to be taken: [1] proper plant design; [2] proper selection of membrane; [3] adequate investigation of quality of water to be treated; [4] uninterrupted supply of electric power; [5] use of non-corrosive material for construction of the plant; and [6] use of trained staff for operation and maintenance (IRMA/UNICEF, 2001).

## Multi-stage Flash (MSF) Distillation

In an MSF distillation system, sea water vaporization takes place at low temperatures in vacuum. The vapours condense to form fresh water. At vacuum pressures the boiling point of water is low, requiring less energy. A brine heater heats the sea water to around 90 to 115 deg C (Osman *et al.*, 1999). Before reaching the brine heaters the cold sea water passes through condensing coils in the vacuum flash chambers. This has the dual function of: preheating the cold sea water before entering the brine heater; and condensing the flashed steam in the chambers to produce fresh water.

The hot brine then enters the flash chamber which is at a vacuum. Since the entering water temperature is higher than the boiling temperature at that vacuum pressure, a part of the water flashes to steam. The steam rises to the upper part of the chamber and on contact with condensing coils condenses to form pure water. The salt and other impurities still remain with balance of the brine at the bottom of the chamber. Steam ejectors produce the necessary vacuum in the flash chambers. The balance brine goes to the next chamber where the process repeats. Multiple chambers increase the quantity of produce water. The balance brine returns to the sea. A 20 % yield of fresh water is possible in MSF systems.

The initial investment for flash distillation plant is two times more as compared to plants using Reverse Osmosis technology. But the operation and maintenance cost for flash distillation plant is much less (50 to 65 per cent). It requires an initial investment of about Rs.1 crore for a plant having a capacity of 100 $m^3$ of desalinated water per day. The initial investment includes that for plant, machinery, piping and other infrastructure requirements. The cost of operation and maintenance has been estimated at Rs.30 per $m^3$ of desalinated water; with the inclusion of the cost of capital, the cost of water is estimated to go up to Rs.60 per $m^3$ (IRMA/UNICEF, 2001). A case study of multi stage flash distillation technology in Jamnagar by Reliance Industries is given in Box 1.

The cost of production of freshwater under different desalination technologies are given in Table 15.

## Co-generation of electricity and desalinated water

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10 For example, in a fishery unit in Porbandar, an RO plant of 200,000 litres capacity purchased at a cost of about Rs. 35.00 lac in 1990 has been found to be out of service since inception. The major reason for the condition is the wrong assessment of input water quality by the supplier of the plant as about 8,000 ppm TDS, while in practice, the TDS was about 40,000-50,000 ppm for seawater and about 6000 ppm for groundwater. RO plants were established in 18 villages spread over six talukas of Jamnagar district adjoining the seacoast under the Technology Mission Programme for making sweet water from saline water. All the 18 RO plants are currently out of service due to several reasons.

In recent years, there has been increasing recognition of the scope for co-location of desalination plants with power plants has (Al-Nashar, 2001; Hoffman and Zfati, 2003; Agashichev and El-Dahshan, 2003; Lokiec and Kronenberg, 2001). In fact, about 95% of the total potable water production capacity in the MENA countries is produced via cogeneration (Hoffman and Zfati, 2003). The choice of the type of power plant and desalination technology is an important one and is highly dependent on site-specific conditions and economic consideration (Hoffman and Zfati, 2003). The vast majority of cogeneration facilities worldwide are powered by fossil fuel power plants (i.e., coal and oil). In the coupling of steam-generating power plant and a thermal desalination plant, heat in the form steam generated by the power plant is used as the source of heat for the co-located desalination plant (Al-Nashar, 2001; Hoffman and Zfati, 2003; Faibish and Ettouney, 2003). Furthermore, the warm reject brine from the thermal desalination plants can be used as feed to an RO membrane desalination plant, where the preheated feed yields a higher overall permeate flux and, thus, reduces the required membrane surface area for a given capacity (Hoffman and Zfati, 2003; Henthorne, 2001; Hanra, 2000). It should be also noted that the viscosity of the feed brine is reduced at higher temperatures, which results in decreasing pumping requirements of the feed through the membrane modules). The hybrid plant option (namely, thermal + RO plants) can also solve severe power-water demand mismatch problems, which are frequently encountered in arid, dessert-like regions around the world and especially in the MENA regions (Hoffman and Zfati, 2003; El-Sayad *et al.*, 1998; El-Sayad *et al.*, 2000).

India has already commissioned a larger than 6000m$^3$/day demonstration hybrid thermal (Multi-Stage Flash Distillation, MSF) and Reverse Osmosis (RO) system with an existing pressurized heavy water nuclear power plant (PHWNPP) in the southern region of Kalpakkam. Multi-Effect Distillation demonstration plant to an existing PHWNPP in the large metropolitan area of Karachi. Kazakhstan has been using the largest nuclear desalination complex to date in Aktau. There, a thermal desalination system was coupled to a fast reactor to supply close to 80,000m $^3$/day of freshwater to the surrounding population.

In the U.S., a membrane desalination facility was coupled to the Diablo Canyon Nuclear Power Plant in California. The water intake and outtake systems are shared between the NPP's cooling water systems and the membrane plant. The plant supplies about 4500m3/day of freshwater to the plant. The water plant has been operated with such efficiency that membrane elements, which are typically replaced every 3-5 years, have not been replaced for over 10 years now. It should be noted that the surrounding communities have been recently showing interest in obtaining potable water from the plant. Other potential sites in the U.S. include various sites along the Californian, Texas, and Florida coastal regions, as mentioned above. In-land regions may also be considered for desalination of highly brackish water as well as shipped-in seawater, if the economics are right. It is also worth to note that nuclear power plant release negligible amounts of greenhouse gas emissions to the environment. Indeed, the releases are more than 2-orders of magnitude (approaching nil) as compared with other power plants (Faibish and Ettouney, 2003).

The economics of water/power cogeneration also seems to favour further application of the concept based on reduced cost of co-locating the desalination and power generation facilities. Water generation cost in a recently completed project in southern Israel is as low as 0.50 USD/m$^3$. The most obvious need in advancing future application of this much needed cogeneration solution is the optimization of such coupled systems – both technical and economic optimization. Such a task requires careful analysis on a case-by-case basis of potential future sites, which may greatly benefit from water and power cogeneration. For developing countries, small medium conventional as well as renewable energy power sources are more favourable in the short run for cogeneration considerations due to overall initial investment costs and lack of required infrastructure. Thus, it is clear that option other than nuclear as the source of power must be considered and thoroughly assessed (Faibish and Ettouney, 2003).

Table 15: Economics of Desalination under Different Technologies

| Sr. No | Type of raw water | Technology | Level of salinity | Cost of water Treatment (Rs/m$^3$) | Remarks |
|---|---|---|---|---|---|
| 1 | Seawater desalination | Reverse Osmosis | 25,000 ppm+ | 30.0-105.0 | The cost is a function of the plant size & potential utilization |
| 2 | Desalination of brackish groundwater | Reverse Osmosis | 5,000-6,000 ppm | 27.0-30.0 | Do |
| 3 | Desalination of seawater | Multi-stage Flash distillation | 40,0000 and above | 60.00 | Freshwater recovery is 20%; the cost significantly reduces if coupled with power plant (thermal nuclear) to Rs. 25 per m3 of water |
| 4 | Brackish water | Electro dialysis | < 5,000 ppm | | |

Source: based on Shah et al., 1997; IRMA/UNICEF, 2001; Osman et al. (1999)

## 7.6 Protection of Groundwater Quality

In humid and sub-humid regions, groundwater table is likely to be shallow in the plains. In such situations, if groundwater is used for urban water supplies, caution should be exercised to prevent likely pollution of aquifers from solid waste disposal sites and landfill sites, and treated and untreated sewage.

An example is the construction of latrine pits at Tota-Bengare, Mangalore. People depend on hand pumps for drinking water, as groundwater table is only four feet below ground level. The project planned piped water supply and construct latrine pits. The implementing agency had not analyzed the situation and the impact of providing piped water supply and the latrine pits on the local fresh water resources. Instead, the project went ahead with the construction of latrine pits and laying the water supply lines. The people of Tota-Bengare are on the receiving end as their local water resources are being polluted, and the increasing external dependency on the piped water supplies (ADB, 2007).

The pollution of groundwater can be bacteriological, and biochemical (CPCB, 2008). The landfill sites should be made impervious. Pit type latrines should be avoided in shallow water table areas. The sewage should be treated free of chemical and biological contaminants, and if possible bacteriological contaminants. But, it is also important to see whether good hygiene practices could be promoted among the urban dwellers to consume boiled water which would be free from pathogens. Kerala provides an illustrative example for legal measures in promoting good hygiene practices. The municipalities and corporations have passed acts that make it mandatory for hotels and restaurants to serve only boiled water to their customers.

Intermittent supply leads to many problems including, severe supply pressure losses and great inequities in the distribution of water. Another serious problem arising from intermittent supplies, which is generally ignored, is the associated high levels of contamination. This occurs in networks where there are prolonged periods of interruption of supply due to negligible or zero pressures in the system (Vairavamoorthy et al., 2007).

In shallow groundwater areas of eastern India (eastern UP, Bihar, WB, Assam and parts of Orissa), on-site sanitation could be a big source of biochemical and bacteriological contamination of groundwater. The reasons are the sub-humid to humid climate; low temperature in most parts of the year; shallow unsaturated sub-strata and moist soil conditions. All these factors lead to reduced resident time for the effluent, and also better survival of the bacteria and virus. In areas with structured soils, and with fractures/fissures in the underlying formations, short-circuiting of the strata would be possible increasing the chances of both bacteriological and bio-chemical contamination. In hard rock areas with shallow groundwater (in peninsular India), chances of contamination of groundwater would be very high especially when the hydraulic loading is high (see Section 7.1.1 for references). Therefore, untreated effluents disposed off into water bodies such as ponds, lakes and streams would be a major source of groundwater contamination.

Treating wastewater or effluent to safe limits (of biochemical and bacteriological contamination) would be important. Also, proper selection of sanitation systems with due consideration to the geo-hydrological environment, soil characteristics, climate (temperature, and humidity/aridity) and rainfall would be of critical importance.

# 8.0 PHYSICAL OPTIONS FOR WATER DEMAND MANAGEMENT

In this chapter, we would discus three important aspects: treatment of wastewater in order to reduce the demand for water for pollution assimilation; reuse of wastewater that increases the effective availability of water for future water supplies; and methods for reducing the distribution (network) losses in water supply systems that can reduce the supply requirement at source.

## 8.1 Wastewater Treatment Options

### 8.1.1 Physical Considerations for Design of On-site Sanitation Systems

On-site sanitation systems can lead to contamination of groundwater sources. The contamination takes place in the event of a pathway existing between a source i.e., on-site sanitation system and a receptor i.e. groundwater body. Groundwater pollution due to on-site sanitation systems has been dealt by many workers (Gerba and Bitton, 1984; Chidavaenzi et al, 2000).

Concern about groundwater pollution due to on-site sanitation system relates primarily to unconfined and, to a lesser degree, to semi-confined aquifers. If groundwater supplies are drawn from deep and confined aquifers, on-site sanitation does not pose a significant hazard. Recent studies by Lawrence et al. (2001) highlight the role of hydrogeology in determining the degree of contamination of groundwater from on-site sanitation. Studies carried out in USA on groundwater pollution from septic tank effluent have been a major source of information. However, effect of the difference in the design and construction of septic tank disposal systems, and the proposed sanitation systems may be significant. The studies carried out were in Columbia in sand-clayey sand (Kligler, 1921), Alabama in fine-sand medium (Caldwell, 1938). Besides studies were conducted in sandy clay in Texas (Brown *et al.*, 1979) and fractured rocks in Colorado (Allen and Morrison, 1973).

The majority of the field studies were confined, mainly to fine-grained sediments, which are of low risk, and consequently most suitable for on-site sanitation. There is a need to obtain more information on other soil types. There is a need for a classification of hydro-geological environments in relation to pollution risk. This would be of great value in the appraisal and implementation of on-site sanitation schemes.

The factors affecting the pollution of groundwater from on-site sanitation, which are well documented, are as follow: depth to water table; hydraulic loading; the structure and texture of soils in the unsaturated zone; and presence of fissures in the case of hard rock formations. Their role is discussed below.

- The chances of contamination increase significantly in geological settings where the water table is very shallow (1m-15m)

- The unsaturated zone represents the first line of defence against aquifer pollution. Soil provides a very effective natural treatment system. It has ability to remove faecal micro-organism and chemical/biochemical compounds. The nature of the geological strata and thickness of the unsaturated zone determine risk of pollution. While natural flow rates in the unsaturated zone of almost all formations does not normally exceed 0.3 meter/day (Lawrence et al., 2001), it can be more than an order of magnitude higher in case of fractured formations. Flow rates in excess of 5 meter/day may occur in fissured rocks and coarse gravel (Franceys et al., 1992) and the potential for groundwater contamination under these conditions is extremely high. Thus rock type, especially the grade of consolidation and presence of fractures, are key factors in assessing vulnerability of aquifer to pollution.

- The key factor in reducing micro-biological contamination of groundwater is the maximization of effluent residence time in the unsaturated zone. Many contaminants, especially the micro-organisms are rendered harmless or reduced to low concentrations by natural processes when the movement of the contaminants in the sub-surface is slow. The natural treatment processes, such as filtration, are more efficient in fine-grained unstructured soils. Structures such as root channels, animal burrows, natural voids and fissures commonly lead to short-circuiting of the unsaturated zone with consequent reduction in the residence time and natural treatment. This may lead to greater risk of groundwater pollution.

- Clogging of the filtration surface in the latrine pit enhances bacteria and virus removal processes so that the risk of pollution from micro organisms diminishes after the first 100 days or so of pit usage. But, it can reduce the infiltration of the effluent, thereby affecting the capacity to reduce the BOD, COD nitrate etc.

- More specifically, the risk of microbiological groundwater pollution will be minimal where more than 2 m of fine unsaturated soils are present beneath the latrine pit, provided the hydraulic loading in the pit does not exceed 50 mm/day.

- In the saturated zone, pollutants move with the groundwater causing a pollution plume to develop from the pollution source. Contamination removal processes take place in the saturated zone but at a lesser rate compared to unsaturated zone since groundwater moves more rapidly. Within the saturated zone, dispersion and dilution play an important role in reducing the concentration of the contaminants.

Improper design, construction, operation or maintenance of on-site sanitation systems can lead to failure due to the loss of infiltration capacity, with consequent surfacing of effluent. Such failures are quite frequently reported. In well-designed septic tanks, the solid matter does not represent a significant hazard, but the soak pit causes both microbiological and chemical contamination. There is potential threat to groundwater where hydraulic loads are high and they exceed natural attenuation potential in the sub-surface. However, an equally important and more insidious failure is that of inadequate effluent purification.

The organic matter gets filtered while passing through the soil formations. They also get adsorbed and digested through aerobic and anaerobic processes. The micro organisms (bacteria, virus and fungi) get adsorbed.

Adsorption of both viruses and bacteria is highest in soils with high clay content, and is favoured by a long residence time – that is, when flow rates of effluent are slow. Since the flow is much slower in the unsaturated zone than in the saturated zone, the contact time is longer between soil and effluent and thereby increasing the chances of adsorption. Adsorbed microorganisms can be dislodged, for example by flushes of effluent or following heavy rainfall, and may then pass into lower strata of the soil.

Both viruses and bacteria live longer in moist conditions than in dry conditions. Bacteria live longer in alkaline soils than in acidic soils. The bacteria also survive well in soils containing organic material, where there may be some regeneration.

The survival of bacteria and virus in soils also depend on the temperature. The reduction of polioviruses held for 84 days in loamy sand was less than 90% at 4°C, but 99.99% at 20°C. Also it was found that aerobic inactivation was more rapid under non-sterile versus sterile conditions, and that anaerobic conditions led to a reduction in inactivation. In nutshell, while the formation conditions influence the removal process, the survival of these micro organisms in the formations depend on the temperature, pH value, moisture content etc. But, the dominant factors for bacteria survival are temperature and moisture (Gerba *et al.*, 1975).

### 8.1.2 Waste Stabilization Ponds

It is particularly well suited for tropical and subtropical regions as intensity of the sunlight and temperature are key factors for the efficiency of the removal processes. They have three important components: 1] anaerobic ponds for removal of BOD (60%); 2] facultative pond for further removal of BOD with the help of algae[11]; and 3] removal of pathogens and faecal coliforms using algae. The removal especially of pathogens and faecal coliforms is ruled by algal activity in synergy with photo-oxidation in the maturation pond. In the maturation pond, removal of nitrogen and phosphorous also take place. The extent of removal is nearly 80 per cent for nitrogen and 95% for ammonia.

In anaerobic ponds, organic matter is normally converted into ammonia and methane through anaerobic digestion, whereas in facultative pond, further oxydation of the organic matter takes place. The process of oxidation of organic matter by aerobic bacteria is usually dominant in primary facultative ponds or secondary facultative ponds. In anaerobic ponds, BOD removal is achieved by sedimentation of solids, and subsequent anaerobic digestion in

[11] Their performance improves under strong winds which facilitate good distribution of BOD, dissolved oxygen and algae, and hence better waste stabilization.

the resulting sludge. The anaerobic bacteria are usually sensitive to pH <6.2. Thus, acidic wastewater must be neutralized prior to its treatment in anaerobic ponds. A properly-designed anaerobic pond will achieve about a 40% removal of BOD at $10_o$ C, and more than 60% at $20_o$ C. A shorter retention time of 1.0-1.5 days is commonly used.

Arthur (1983) compared the economics of waste stabilization ponds, aerated lagoons, oxidation ditches and trickling filters. The data for this study were taken from the city of Sana'a in the Yemen Arab Republic (Arthur, 1983). If the cost of land is considered a variable for a constant discount rate (opportunity cost of capital) of 12%, then the waste stabilization pond technology is a cheaper option up to a land cost of U.S $ 7.8/$m^2$. Above this cost, oxidation ditches become the cheapest option. For discount rates between 5 and 15%, the choice will always be between waste stabilization ponds and oxidation ditches. The other two systems considered are more expensive (Arthur, 1983).

Further analysis showed that for land cost of US $ 5/$m^2$, the WSP was cheaper for discount rate of up to 15%, but the discount rate corresponding to cost effectiveness of the technology reduced with increasing land prices, and the system was found to be viable up to a discount rate of 9.75 per cent for land price of US $ 10 and 5.3 per cent for land price of US $ 15/$m^2$ (Arthur, 1983: p58).

WSP also does only up to secondary treatment of wastewater. The nutrients (nitrates formed from nitrification of ammonia and phosphorous) are not fully removed from the wastewater. The nitrogen and ammonia removal from the WSP are 80 per cent and 95%, respectively. These high-nitrate containing water, if fed to crops, can damage the soil in the long run.

Studies in Colombia (Peña *et al.*, 2002) using physical, technical and socio-economic feasibility estimates show that waste stabilization ponds are extremely useful for wastewater treatment in small municipalities. While land price was not a constraint for adopting the technology (as the price was lower than US $ 7.8/$m^2$), land availability was found to be a constraint in towns located in hilly areas (Peña *et al.*, 202). But, it is important to remember that the land area required for WSP (pond size) is directly related to the population served and to on-site temperature.

The land area requirements of an anaerobic and facultative pond system vary from 1.8 to 0.5 $m^2$ per person for temperatures from 12 to 27ºC, respectively. Inclusion of maturation ponds increases the area requirement to 2.8 to 0.7 $m^2$ per person for the same temperature range (Table 16). In terms of removal efficiencies, an AP+FP system may remove around 80% of both BOD5 and TSS, and an AP+FP+MP system may increase this to around 90% for both parameters. The overall hydraulic retention time varies from 20.2 to 5.4 days for AP+FP, and from 27.1 to 9.0 days for AP+FP+MP, for the same temperature range mentioned above (Peña *et al.*, 2002). However, the system including maturation ponds will produce an effluent safe for restricted irrigation (WHO, 1989).

When land cost is reasonably low and the ponds serve small communities, and the temperature high, WSP systems are highly competitive in comparison to other treatment alternatives.

Table 16: Land area requirements for WSP systems with and without maturation ponds (per person)

| Temperature ($^o$ C) | AP + FP (m2) | AP + FP +MP (m2) |
|---|---|---|
| 12 | 2.2 | 3.4 |
| 14 | 1.6 | 2.6 |
| 16 | 1.3 | 2.0 |
| 18 | 1.0 | 1.6 |

| | | |
|---|---|---|
| 20 | 0.7 | 1.3 |
| 22 | 0.7 | 1.2 |
| 25 | 0.6 | 1.0 |
| 27 | 0.6 | 0.8 |

Source: Peña *et al.* (2002)

AP = Aeration pond; FP =Facultative pond; MP +Maturation pond

Criteria for studying feasibility of WSP are: 1] physical, comprising geographic location; land availability; and meteorological aspects; 2] socio-economic, comprising population distribution, and cost of land; and, 3] technical, comprising sewerage coverage, sewerage functioning, sewerage management, and wastewater treatment.

Design Criteria for WSP

The area required for WWT using WSP =p *Ã

Here, Ã is the area required for AP +FP +MP pond per unit of population, which is again a function of the temperature and (can be obtained from Table 4) and "p" is the urban population. The temperature of the city ($T$) can be decided on the basis of the mean value for the coolest month.

The value of "Ŧ", which is the hydraulic retention time, varies from 27 to 9 days depending on the temperature, with highest value for 12° centigrade to the lowest value of 9 days for a temperature of 27° C. For aeration pond, the detention time is assumed as 1 to 1.5 days, depending on the temperature (Peña *et al.* (2002).

**Detailed Design**

Anaerobic Pond

The design is based on volumetric organic loading considerations. The volume of storage required for hydraulic retention in the aeration pond=

Ŧ *p*0.85*θ........................................................ (1)

Where, θ is the daily per capita water demand ($m^3$) in the urban area

Ideally, the retention time "Ŧ" is estimated on the basis of the effluent BOD (L in mg/l) and the permissible volumetric organic loading (λ in gm/m3.day) as:

L/ λ ....................................... (2)

But, λ is determined by the temperature. The temperature (which is the mean monthly temperature of the coldest month or quarter of the year), determines λ as per the Table 17.

Table 17: Safe Organic Loading Levels for Different temperature Ranges in Anaerobic Ponds

| Sr. No | Temperature Range | Safe Organic Loading | BOD Removal % |
|---|---|---|---|

| | | | |
|---|---|---|---|
| | | (gm/m$^3$.day) | |
| 1 | < 10 Degree centigrade | 100 | 40 |
| 2 | 10-20 degree Centigrade | 20T-100 | 2T +20 |
| 3 | 20-25 | 10T+100 | 2T +20 |
| 4 | ➢ 25 | 350 | 70 |

Source: Mara et al. 1992

Facultative Pond

It is designed on the basis of surface organic loading (λ in gm/m2.day) criteria, which is estimated as:

$\lambda = L*Q/A_f$ ………………………… (3)

The surface loading, which is a function of temperature, is

$\lambda = 350\ \{1.107 - 0.002T\}^{(t-20)}$ …… (4)

We can use the above equation to estimate the value of $A_f$. Using $A_f$ Ŧ value for the facultative pond can be estimated as:

$A_f = Q_m D/_{Ŧ}$ ……………………….. (5)

The depth of the pond ($D$) should be adjusted in such a way that the minimum value of hydraulic retention time becomes 5 days.

Maturation Pond

Is designed on the consideration of effluent bacterial load as:

$N_e = \frac{N_i}{(1+Ŧ*K_T)}$ …………………….. (6)

$N_e$ is the coliform count for the effluent from the Maturation Pond, and $N_i$ is the coliform count of the influent. $K_T$ is the first order rate constant for faecal coliform removal, and is a temperature dependent variable. Depending on the desirable level of effluent coliform count, the coliform count in the influent organic load, and the temperature, the hydraulic detention time "Ŧ" (days) can be worked out.

$K_T = 2.6\{1.19\}^{T-20}$ ……………….. (7)

**Nitrification & De-nitrification**

Nitrification is the process of conversion of food into ammonia and then into nitrates by a bacterial degradation process[12]. Further conversion of nitrates into nitrogen requires both bacteria and some specialized chemical compounds like methanol. De-nitrification is a process involved in the treatment of wastewater. As wastewater is collected

12 Conversion of ammonia into nitrate takes place only under aerobic conditions.

in a treatment facility, it contains high levels of ammonia. Through a bacterial degradation process this ammonia is converted into nitrate. If discharged into the environment, the nutrient-rich nitrate in sewage effluent can have a devastating effect on water ecosystems. De-nitrification refers to the process using a combination of chemical additives and bacterial degradation to convert nitrate (NO3) into nitrogen gas (N2) which is released to the atmosphere. Methanol activates anaerobic bacteria, which decomposes nitrates into nitrogen gas.

### 8.1.3 Soil Aquifer Treatment

SAT (soil aquifer treatment) is a geo purification system where partially treated sewage effluent artificially recharges the aquifers, and then withdrawn for future use. By recharging through unsaturated soil layers, the effluent achieves additional purification before it is mixed with the natural groundwater. In water scarce areas, treated effluent becomes a considerable resource for improved groundwater sources. The Gaza Coastal Aquifer Management Program includes treated effluents to strengthen the groundwater, in terms of both quantity and quality. With nitrogen reduction in the wastewater treatment plants, the recharged effluent has a potential to reduce the concentration of nitrates in the aquifer. In water scarce areas such as in the Middle East and parts of Southern Africa, wastewater has become a valuable resource that, after appropriate treatment, becomes a commercially realistic alternative for groundwater recharge, agriculture, and urban applications (SIDA, 2000).

SAT systems are inexpensive, efficient for pathogen removal, and operation is not highly technical. Most of the cost associated with an SAT is for pumping the water from the recovery wells, which is usually $20-50 USD per m$^3$. In terms of reductions, SAT systems typically remove all BOD, TSS, and pathogenic organisms from the waste and tend to treat wastewater to a standard that would generally allow unrestricted irrigation. The biggest advantage of SAT is that it breaks the pipe-to-pipe connection of directly reusing treated wastewater from a treatment plant. This is positive attribute for those cultures where water reuse is taboo (Rose, 1999). The details of the SAT schemes running in the two cities of Israel are given in Table 18A.

Table 18 A: Details of SAT schemes in Soreq and Yevne, Israel

| Particulars | Soreq | Yevne |
|---|---|---|
| Cumulative hydraulic load** | 1416 m | 1600m |
| Total volume of water recharged* | 850 | 400 |
| Year of operation | 25 | 15 |
| First recharge year | 1977 | 1987 |
| Area in ha for recharge (ha) | 60 | 25 |

Source: Idelovitch (2003)

* Volumes recharged are cumulative until 2001

** Load corresponds to ~2000 years of natural rainfall
(700-800 mm per year)

The pre treated effluent is pumped into the recharge basin first. The water infiltrates through the vadoze zone of 37 m depth and recharges the aquifer. There are several observation wells located around the recharge basin to analyze the reduction in organic and inorganic pollutants. The recovery wells are located at a distance. The analysis of samples collected from observation wells shows sharp reduction in BOD through bio degradation and adsorption. Good nitrogen removal is generally achieved by nitrification-denitrification, ammonia adsorption and particulate N filtration. Phosphorus removal is excellent by chemical precipitation and adsorption

Reduction in infiltration capacity of the recharge basin can significantly affect the efficiency of removal of organic and inorganic pollutants. This is due to the formation of predominantly anaerobic conditions in the soil-aquifer system. Therefore, it is important to ensure sufficient drying periods for oxygen penetration into the soil. Also, the top soil needs to be scrapped to remove the organic matter and the chemical precipitates. The pollutant removal efficiency of SAT for different types of pollutants is given in Table 18B.

Table 18B: Pollutant Removal Efficiency in SAT

| Name of the Pollutant | Concentration Before SAT | Concentration After SAT | Efficiency of Removal |
|---|---|---|---|
| SS | 10-80 | 0.0 | 100 |
| BOD | 5-40 | 0.50 | 98 |
| COD | 40-160 | 10-20 | 85 |
| $COD_f$ | 40-80 | 10-20 | 75 |
| DOC | 15-20 | 3-6 | 74 |
| UV Absorption | 150-400 | 30-80 | 80 |
| Detergent | 0.40-1.0 | 0.05-0.20 | 82 |
| **Total N** | **5-30** | **5-10** | **57** |
| Total P | 3-10 | 0.01-0.03 | 99 |

Source: Idelovitch, 2003

The pre treatment requirements for SAT vary depending on the purpose of groundwater recharge, sources of reclaimed water, recharge methods, and location. Some may only need primary treatment or treatment in a stabilization pond. However, pre treatment processes should be avoided if they leave high algae concentrations in the recharge water. Algae can severely clog the soil of the infiltration basin. While the water recovered from the SAT system has much better water quality than the influent, it could still be lower quality than the native groundwater. Particularly, the concentration of nitrate in the recharge water would be high (see Table 18). Therefore, the system should be designed and managed to avoid intrusion into the native groundwater and use only a portion of the aquifer. The distance between infiltration basins and wells or drains should be as large as possible, usually at least 45 to 106 m to allow for adequate soil-aquifer treatment (Metcalf and Eddy Ltd., 2002).

The estimates of cost of production of treated water using SAT in Israeli sites against cost of water production from conventional sources are given in Table 19.

Table 19: Economics of SAT: The Israel Experience

| Sr. No | Source of Water | **US $/100m$^3$** |
|---|---|---|
| 1 | Conventional Water Sources | 25-30 |
| 2 | Wastewater Reuse | |
| | a. Secondary biological treatment | 5-15 |
| | b. Tertiary chemical treatment | 10 |
| | c. Deep reservoir treatment | 7-15 |
| | d. Soil aquifer treatment | 17 |

| | | |
|---|---|---|
| | e. Total DRT (a+b) | 12-30 |
| | f. Total SAT (a+ d or a+ b+ d) | 22-42 |
| 3 | Desalination of brackish water | 40-60 |
| 4 | Desalination of sea water | 60-100 |
| 5 | Dan Region Project | |
| 6 | Treatment prior to SAT (a or a + b) | 15 |
| 7 | SAT (d) | 17 |
| 8 | Conveyance and Distribution after SAT | 13 |
| | Total Dan Region Project at point of use | 45 |

Source: Idelovitch, 2003

Note: Cost of SAT (item d) includes that of recharge, monitoring and pumping

Design Criteria for SAT

Depth of vadoze zone= 35-40 metre

Area ($m^2$) required for hydraulic loading under SAT (Ã) = v/ µ

Where, "v" is the total daily volume of effluent ($m^3$); and "µ" is the infiltration capacity of the soil in m/day[13];

The variable "v" can be estimates as: p*0.98*θ

Source: Waste Stabilization Ponds and Constructed Wetlands, Design Manual

### 8.1.4 Constructed Wetlands

Constructed wetlands are used for wastewater with low suspended solids content and COD concentrations below 500 mg/l. It is an excellent technology for upgrading septic tank effluent to a very high quality. Hence, this is an appropriate technology for decentralized wastewater treatment method for housing stocks and commercial establishments, which are not connected to sewerage systems (GTZ, undated).

Many trophic levels of organisms live in and on the filter bed, and the very large surface area of the media results in the process being relatively "low-rate". Due to these characteristics, failure will be slow and gradual, the mode of failure usually being clogging of the filter bed. Therefore, in case of failure, water will no longer flow through the bed at the charging rate, rather than poorly treated effluent will be leaving the plant.

There are three basic treatment systems. These are: the overland treatment system; the vertical flow filter, the horizontal flow filter. For overland treatment, the water is distributed on carefully contoured land by sprinklers or channels. The system requires permanent attendance and maintenance. For vertical filter treatment, the wastewater is distributed by help of a distribution device to two or three filter beds, which are charged alternately. Charging intervals must be strictly followed which makes the vertical filter comparably difficult to operate. The horizontal filter is simple by principle and has a very low

[13] In the case of Israel's DAN projects, a daily average infiltration of 15 cm was obtained in the case of Soreq, and 29 cm in the case of Yevne.

maintenance demand, given that it has been well designed and constructed. Design and construction require a solid understanding of the treatment process in general and a good knowledge of the respective filter medium used (Kayambo *et al.*, 2004).

### 8.1.5 UV Disinfection of Drinking Water Supplies

Ultra violet lights in the wavelength of 240-280 nanometres (nm) have the capacity to kill bacteria and viruses, or deactivate them thereby preventing them from multiplying. A recently innovated device uses UV light (254nm) to inexpensively disinfect community drinking water supplies. Its novel features are: low cost (about US $600), robust design, rapid disinfection (12 seconds), low electricity use (40W), low maintenance (every 6 months), high flow rate (15 l/min) and ability to work with un-pressurized water sources. The device could service a community of 1000 persons, at an annual total cost of 14 US cents per person. The disinfection is in the order of 6 logs. The UV dose, measured in microwatt-seconds per square centimetre, is the product of UV intensity and exposure time. A dosages for a 90% kill of most bacteria and viruses range from 2,000 to 8,000 μW-s/$cm^2$, while dosages for Giardia, Cryptosporidium, and other large cysts and parasites are an order of magnitude greater (approximately 60,000-80,000 μW -s/$cm^2$) at a minimum (Wolfe, 1990). If high dosage is not given, some of the bacteria can reactivate after some hours in the presence of sunlight.

### 8.1.6 Sludge Upflow Anaerobic Blanket

Anaerobic process using blanket of bacteria to absorb polluting load; suited to hot climates. Produces little sludge, no oxygen requirement or power requirement, but produces a poorer quality effluent than processes such as ASP. (NOTE: other anaerobic processes exist, but UASB is the most common at present).

### 8.1.7 Performance of Different DWWTSs

The performance of the different treatment systems depends on the influent characteristics and temperature, but can be defined by the following approximate BOD removal rates: 1] 25 to 50% for septic and Imhoff tanks; 2] 70 to 90% for anaerobic filters and baffled septic tanks; and 3] 70 to 95% for constructed wetland and pond systems. The performance details for different decentralized wastewater treatment systems are given in Table 20.

These values, influent quality, and the required effluent quality decide the choice of treatment systems. For example, septic tanks will be suitable for treatment in areas where the groundwater level is low. For a maximum BOD discharge of 50 mg/l, the anaerobic filter in combination with a septic tank can be sufficient for wastewater of 300 mg/l BOD without further post treatment. Stronger polluted wastewater would require a constructed wetland or pond system for final treatment (source: GTZ, Technical Information W8e). The following values indicate the approximate permanent land demand for setting up a treatment plant:

Table 20: Performance of different types of decentralized wastewater treatment systems

| Sr. No | Type of treatment system | Efficacy of Treatment (% BOD reduction) | Permanent area ($m^2$) required per $m^3$ of daily inflow | Suitability |
|---|---|---|---|---|
| 1 | Septic Tank/Imhoff | 25-50 | 0.5 | ST is suitable for deep |

| | | | | |
|---|---|---|---|---|
| | Tank | | | WT areas only<br>IT suitable for up to $3m^3$/day of influent |
| 2 | Anaerobic filter/ Baffled Septic Tank | 70-90 | 1.0 | In AF, non-settleable and dissolved solids are removed by bringing them in contact with active bacteria<br>A good filter provides a surface area of 90-300 $m^2$ per $m^3$ of reactor volume |
| 3 | Facultative aerobic pond | 80-90 | 25.0 | Land area required is large; but actual area also depends on the temperature |
| 4 | Anaerobic pond | 75-90 | 4.0 | Produces low quality, but less sludge; suitable for hot regions |
| 5 | Constructed wetlands | Do | 30.0 | To treat effluent from septic tanks |
| 6 | Waste Stabilization Pond | 90 | 6.40-19.20 | Sunlight and heat required. The area depends on the temperature |

Sources: based on Peña *et al.* (2002); WHO (1989); GTZ Technical Information W8e

The required area, however, increases with the degree of pollution. In case of closed anaerobic systems, there may be no land requirements as they are usually constructed underground. In addition, the area for sludge drying beds will range between 0.1-10 $m^2/m^3$ of daily flow, depending on degree of pollution and de-sludging intervals.

### 8.1.8 Energy Recovery via Anaerobic Treatment[14]

Anaerobic sewage treatment has so far been applied mainly in the tropical regions (e.g. India, Indonesia, Colombia and Mexico). At present anaerobic treatment of dilute sewage is not an option in regions with sewage temperature below 15 0C, since degradation processes occurs at very low rates under such conditions. Producing more concentrated sewage will, in future, favour the introduction of anaerobic systems also in colder regions, since (part of) the biogas may be used to increase the temperature of the smaller volumes of concentrated sewage[15].

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14 This section is based on Gijzen (2001) nd Ensink et al. (2002).

15 The generation of biogas from dilute domestic sewage is not attractive. Anaerobic treatment becomes much more rewarding when high strength sewage is produced. For the long term, low water use or even dry sanitation practices may be introduced in combination with modern collection and anaerobic composting processes. Another intervention to reduce wastewater dilution is the un-

Besides the generation of energy, anaerobic pre-treatment of wastewater may have additional benefits for re-use oriented treatment schemes. The anaerobic conditions in the reactor may reduce the level of (toxic) metal compounds in the effluent due to the formation of insoluble metal sulphides, which precipitate into the anaerobic sludge. As a result the danger of accumulating metals into the food chain via agriculture or aquaculture applications of the effluent may be significantly reduced. For the long-term, industrial effluents need to be dealt with separately from domestic sewage.

An additional positive outcome of anaerobic pre-treatment is expected from the efficient hydrolysis of organic forms of nutrients into mineralised forms. Organic nitrogen in the influent of an anaerobic reactor will leave the system mainly as ammonia. This is the preferred form of nitrogen for most plants and therefore presents optimal conditions for irrigation or for the production of aquatic plants in subsequent pond systems. Anaerobic treatment is mainly aimed at reduction of the organic load of wastewater; pathogens and nutrients are not removed and therefore require further attention in post-treatment systems. In nutshell, in low temperature areas, concentrated sewage can be used for anaerobic treatment by recovering biogas from the sewage and using the same for heating the sewage to maintain the min. temperature of $15^0$.

### 8.1.9 Nutrient recovery from wastewater

Modern wastewater treatment systems apply tertiary treatment for the removal of nutrients (N, P) via precipitation or via biological processes. If we look at these processes in the context of the overall food production and consumption cycle, the current practice does not seem to be rational. Let us illustrate this from the point of view of nitrogen.

Once fixed nitrogen has been incorporated into high quality protein and has been consumed as a human food or animal feed, a major part of the nitrogen is released into the environment again in the form of domestic wastewater and manure. When applying costly tertiary biological treatment for nitrogen removal, potentially useful nitrogen compounds are re-circulated to atmospheric N2. This approach appears very inefficient from both an energy and resource utilization point of view. (Gijzen, 2001)

The reuse of nitrate, nitrite, and ammonia, therefore contributes to high energy efficiency in biological systems[16]. For instance, the average retention time of nitrogen in the biosphere is over 4000 years, before it is eventually re-circulated to atmospheric N2. An approach, similar to the situation in natural systems could be adopted in man-made waste management systems as well. In this case, secondary treatment (BOD removal) is combined with the effective re-use of nutrients by aquatic plants and/or by irrigation of crops in agriculture. One such process is use of nitrate/nitrite containing wastewater for weed (aquatic macrophyte) production and using the same as fish feed. The subsequent section deals with the use of wastewater for duck weed production, thereby removing the nitrates (Gijzen, 2001).

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coupling of storm water from the sewer system. Separate conveyance systems for storm water and sewage are therefore recommended.

[16] Once nitrogen has entered the biosphere via biological N2-fixation, it is subject to a series of conversion steps, from plant protein to animal protein, and finally ends up in dead organic matter. When this organic matter is mineralized in the soil, most of the inorganic nitrogen compounds produced (N03 -, NH4 +) are immediately taken up again by plant or microbial biomass for the production of protein. Only a fraction of the total amount of organic nitrogen is re-circulated to N2 via de-nitrification (Gijzen, 2001).

### 8.1.10 Duckweed-based Wastewater Treatment

Use of aquatic macrophytes has been suggested as a low-cost option for the purification of wastewater and simultaneous production of plant biomass (Araujo, 1987; Brix and Schierup, 1989; Gijzen, 1996; Oron, 1994; Reddy and DeBusk, 1987; Skillicorn *et al,* 1993). When applying aquatic plants in shallow ponds, a combination of secondary and tertiary treatment may be realized. In addition aquatic macrophytes assimilate nutrients into a high quality biomass that may have an economic value. This contrasts favourably with advanced costly nitrification/de-nitrification, where nitrogen is converted into atmospheric N2 and therefore will be 'lost' for further re-use.

Various studies have reported the use of water hyacinth, pennywort, water lettuce and duckweed for the efficient removal of nutrients. The economic potential of each plant species for wastewater treatment depends largely on its efficiency to remove nutrients under a wide range of environmental conditions, its growth and maintenance in a treatment system, and the possible application of plant biomass. Water hyacinth has been used most widely, due to its high nutrient uptake capability, but no economically attractive application of the generated plant biomass has been identified so far

Several full-scale applications of duckweed based wastewater treatment systems exist in the USA, Bangladesh and China. Duckweed systems have been studied for dairy waste lagoons (Culley *et al*, 1981), domestic sewage (Oron, 1994; Skillicorn *et al*, 1993, Alaerts *et al*, 1996), secondary effluent (Sutton and Ornes, 1977), waste stabilization pond effluents (Wolverton, 1979) and fish culture systems (Porath and Pollock, 1982; Rakocy and Allison, 1981). Even in moderate climatic conditions duckweed based systems are being advocated for treatment of domestic wastewater from small communities in Belgium and Poland (Nielsen and Ngo, 1995).

Considering an average annual duckweed yield of 20 ton dry weight/ha a year and a protein content of 35%, a protein productivity of about 7 ton/ha a year can be calculated. Compared to soy bean, duckweed produces about 10 times as much protein per ha/year. According to Gijzen (2001), there are a number of concerns that need to be addressed when considering duckweed as a potential feed:

- Due to the efficient absorption of heavy metals and possibly other toxic compounds, duckweed should be cultivated using effluents with low concentrations of such compounds. No information is available on the possible transmission of pathogens if duckweed harvested from domestic wastewater treatment ponds is used as an animal feed.

- Duckweed has high moisture content (about 95%), which will affect the cost of handling, transportation and drying.

- The genera *Lemna* and *Spirodela* may contain high amounts of calcium oxalate. The presence of this component may limit the use of certain duckweed species for non-ruminant and human nutrition. When properly mixed with other feed constituents, no harmful effects are expected.

- The combination of duckweed based wastewater treatment and fish cultivation is being practiced at a small scale in Bangladesh. The pond complex receives wastewater from 3500 capita and is operated at a hydraulic retention time (HRT) of about 21 days. The results over the past years have demonstrated that the system can be managed with a net annual production of over 12 tons fish per ha, yielding a net annual profit of about US$ 2000/ha.

A feasibility study by the World Bank for Pondicherry, a 35,000 inhabitant town in India, shows that a UASB-duckweed system could yield annually 80 ton of duckweed, 30-40 ton of fish and 150,000 $m^3$ of methane gas. Duckweed based fish farms exist in Bhubaneswar and Cuttack. However, the returns are much less when compared to the capital and operating costs (Gijzen, 2001).

### 8.1.11 Re-use of Wastewater for Fish Production

The quality of the wastewater, in combination with the envisaged type of re-use, define the level of subsequent treatment required, as well as the associated treatment costs. Besides possible industrial and urban re-use options, the most important option for re-use of wastewater is related to agriculture and aquaculture. The effluents do not only serve as a source of water but also provide nutrient input for fish and crops in aquaculture or agriculture irrigation schemes, respectively.

Nutrient concentrations in raw sewage are too high for irrigation of most crops. The aim of wastewater treatment, in addition to pathogen, BOD and TSS reduction, should therefore be to bring back N and P levels to around 15 mg/l for N and about 3 mg/l for P. When applying such effluents at an irrigation rate of about 2 m/y, this results in N and P dosage of 300 and 60 kg/ha a year for N and P, respectively. This practice could significantly reduce or even eliminate the use of commercial fertilizer. With respect to aquaculture, a better way to transfer nutrients from wastewater to fish protein could be via macrophyte-based treatment systems, where the plant biomass is used as a fish feed.

### 8.1.12 Activated Sludge Process[17]

The activated sludge process is a technology used for treating domestic and industrial wastewater, where the biological matter is removed from the wastewater through aerobic digestion. It is an energy-intensive treatment technology, where the wastewater is mixed with air through mechanical process. The amount of sludge produced by the treatment process is also very high. Sophisticated process with many mechanical and electrical parts, which also needs careful operator control. Produces large quantities of sludge for disposal, but provides high degree of treatment, when working well.

**Screening and Grit Units:** The purpose is to remove large objects such as logs, branches, rags, and small fish that could damage pumps and clog pipes and channels. This step can also be used for grinding waste to reduce particle size.

**Primary Settling Tanks:** It uses gravity settling to remove particles from water. Sedimentation takes place in the primary settling tanks and is relatively simple and inexpensive. Particulates suspended in surface water can range in size from $10^{-1}$ to $10^{-7}$ mm in diameter, the size of fine sand and small clay respectively. Turbidity or cloudiness in water is caused by those particles larger than $10^{-4}$ mm, while particles smaller than $10^{-4}$ mm contribute to the water's colour and taste. Such very small particles may be considered for treatment purposes, to be dissolved rather than particulate.

17 This section draws heavily on Richard (2003).

Water containing particulate matter flows slowly through a sedimentation tank and is thus detained long enough for the larger particles to settle to the bottom before the clarified water leaves the tank over a weir at the outlet end. Particles that have settled to the bottom of the tank are removed manually or by mechanical scrapers on the site pending their treatment and/or removal. Detention time is typically 3 h in tanks 3 to 5m (10 to 15 ft) deep.

Aeration Tanks: The waste water flows into an aeration chamber usually constructed of steel, poly, fibreglass, or concrete. The chamber normally provides 6 to 24 hours retention time for the waste water. The contents of the aeration tank are referred to as *mixed liquor*, and the solids are called *mixed liquor suspended solids* (MLSS). The latter includes inert material as well as living and dead microbial cells. In the aeration tank, microorganisms are kept in suspension for 4 to 8 hours by mechanical mixers and/or diffused air, and their concentration in the tank is maintained by the continuous return of the settled biological floc from a secondary settling tank to the aeration tank.

Final Settling Tanks: Like primary tanks, final settling tanks may be rectangular or circular, and occasionally square, but they provide longer detention (2h) and lower overflow rates (30-50 $m^3/m^2$.day). The Final Settling Tanks can also be referred to as The Settling Chamber or a Secondary Clarifier. The Final Settling Tanks receives the overflow of the aeration chamber. When the sludge settles to the bottom of the tank, it is still active and it is able to remove more BOD from the waste water. Returning the activated sludge to the aeration chamber on a continuous basis helps maintain and increase the microorganism concentration in the aeration chamber. This is a key factor to increase BOD removal from the waste water. The sludge will continue to build up. Occasionally, some of the sludge should be drained to keep the effluent from deteriorating.

The cleaner water at the top of the settling chamber overflows through openings at the top of the chamber. It can then be treated for reuse or discharged. For less than a 24 hour retention period in the aerobic process, BOD concentration should not exceed about 2,000 mg/l on the effluent.

Thickener: Thickening of activated sludge occurs as a part of the separation of the activated sludge from the mixed liquor in the secondary clarifiers; or it is practiced independently as an additional operation, usually for mixed sludge (primary and secondary). Separate gravity thickening of activated sludge only is not a very effective operation. There are several types of thickeners, the most common being: Gravity Thickening, Thickening by Flotation, and Centrifugal Thickening.

Anaerobic Digester: Anaerobic digestion of organic sludge is generally a two-phase process. In the first phase, complex organic substances are converted into simple organic acids. In the second phase of the process, the simple organic acids are converted into methane and carbon dioxide.

Chlorine Tank: To ensure that water is free of harmful bacteria it is necessary to disinfect it. Chlorination is the most common method of disinfecting public water supplies. Sufficient quantities of chlorine from chlorine gas or hypo-chlorites are added to treated water to kill pathogenic bacteria. Chlorination is a reliable, relatively inexpensive, and easy disinfection method to use.

### Improving the Performance in Activated Sludge Process

Solids present in the primary clarifier effluent are particles too fine to “settle out.” The activated sludge process removes these suspended particles by converting them to settleable solids. It uses a mixed culture of microorganisms including bacteria, protozoa, and rotifers to break down organic wastes into inorganic wastes. The activated sludge process speeds up this natural course by controlling the environment. The “aeration blowers” supply oxygen critical to the survival of the bacteria in the activated sludge process. However, dissolved oxygen (DO) levels that are too high can result in pin flock in clarifiers, severe sludge bulking in some instances, and wastage of electricity. Dissolved Oxygen levels that are too low will not support the survival of bacteria necessary to treat the incoming waste water. Inadequate DO concentration, in effect, can result in inefficient performance of the plants.

The use of handheld DO meters for setting the speed of the blowers of ASP does not allow for process adjustments[18]. For example, when oxygen demand decreases during winter nights due to falling temperatures, this method does not compensate for the decreased need for aeration and wastes power. Conversely, a large oxygen demand during periods of industrial discharge can deplete the DO and wipe out the entire bacteria if the process does not automatically increase aeration.

### Potential Power Savings with Automation

The power consumption in the activated sludge process can be decreased through energy-efficient motors and variable frequency drives (VFD) used with “on-line dissolved oxygen analyzers”. The dissolved oxygen analyzer can be configured to send an electrical signal to a VFD or be used in conjunction with a SCADA. The control system automatically increases or decreases aeration blower speed in response to the measured DO levels in the aeration basin. A 1998 study by the Iowa Association of Municipal Utilities demonstrated the use of such an equipment in the activated sludge process reduced energy costs as much as 25%. In summary, an on-line dissolved oxygen analyzer when used with the plant’s energy-efficient motors, variable frequency drives, and plant SCADA or PLC systems, adjusts aeration operation automatically in response to varying process conditions.

Source: Mike Rousey, Hach Company, Colorado

### 8.1.13 Economic Considerations for Treatment of WW

Economics of wastewater treatment is determined by the cost of the system; the economic value of that treated water. For most land-based wastewater treatment systems such as WSP, ASP, AP, Anaerobic pond, Soil Aquifer Treatment (SAT) and oxydation ditch, cost is a function of the land area required for treatment. The economic viable system is one which requires least amount of land, but gives the optimum level of treatment.

Assessing the economic value of the treated water is not easy. It depends on the kind of opportunities that exist in the urban/peri-urban situation for reuse of wastewater. There are four different types of possibilities: 1] there is a very high demand for the wastewater for irrigation, and currently untreated wastewater is used; 2] there is no demand for wastewater for irrigation, and hence will have to be disposed into streams; 3] there is no demand for

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[18] Operators using handheld DO meters achieve only hit-or-miss readings that are insufficient for optimizing plant operation and energy usage.

wastewater for irrigation, but there is water demand for growing fish; and, 4] currently, untreated wastewater is not used for irrigation or fisheries due to high level of toxicity.

In the first case, the cost of treating the wastewater to the desired levels should be less than the incremental benefits accrued from reduction in the health risks to the irrigators (economic value of health benefits), and the environmental damage caused by degradation of the soil (economic value of the physical benefits) and groundwater quality deterioration (positive externality due to environmental benefit).

In the second and third case, the cost of the treatment system should be less than the benefits derived owing to reduction in the general environmental quality of the stream/river and improvements in aquatic life (positive externality associated with ecological and economic benefits). In the fourth case, the cost of the treatment system should be less than the incremental economic outputs generated from crops irrigated with wastewater (direct economic) and the reduction in environmental risks associated with unsafe disposal of effluents into the streams (positive externality associated with improvement in environmental conditions).

### 8.1.14 WWT Technologies for Different Typologies

The details of wastewater treatment options for different typologies are presented in Table 21A.

Table 21A: Wastewater Treatment Options for Different Rainfall, Climates, Geo-hydrology and Topography

| Typology No. | Type of waste water treatment technologies | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Onsite sanitation | Waste Stabilization Ponds | | | Soil Aquifer Treatment | Constructed Wetlands | Septic Tank | Activated sludge process | Anaerobic Treatment |
| | | Anaerobic ponds | Facultative ponds | Maturation ponds | | | | | |
| | Depth to groundwater table | Temperature, and land availability | Temperature, sunshine and land availability | Temperature, sunshine, land availability and winds | Depth of groundwater table and soil texture | Soil texture and land availability | Depth to ground water table and temperature | Cold climate and land availability | Land availability and temperature |
| 1 | | XXX | XXX | XXX | XXX | | XXX | | |
| 2 | | XXX | XXX | XXX | XXX | | XXX | | |
| 3 | | | | | | XXX | | XXX | |
| 4 | | | | | | XXX | | XXX | |
| 5 | | XXX | XXX | XXX | | | | | |
| 6 | | | | | | XXX | | | |
| 7 | | | | | | XXX | | | |
| 8 | XXX | | | | XXX | | | | |
| 9 | | XXX | XXX | XXX | | | | | XXX |
| 10 | | | | | | | | XXX | XXX |
| 11 | | XXX | XXX | XXX | | | | | XXX |
| 12 | XXX | | | | | | | XXX | |
| 13 | XXX | XXX | XXX | XXX | | | | | XXX |
| 14 | | XXX | XXX | XXX | | | | | |
| 15 | | | | | | XXX | XXX | XXX | |
| 16 | | XXX | XXX | XXX | | | | | XXX |

Source: based on authors' own analysis

Note: XXX indicates the suitable technologies for the typologies under consideration

### 8.1.15 Wastewater Treatment Options for Sustainable Urban Water Management

The first step is to identify the wastewater treatment options that are physically feasible for a given typology on the basis of various considerations such as climate, topography. The physical feasibility is to be ascertained on the basis of the degree of reduction of pollutants in the wastewater. The different wastewater treatment systems which are physically feasible under different rainfall, climate, geo-hydrological and topographical conditions are given in Table 21A. They were arrived at on the basis of extensive research on the performance of various WWT technologies available internationally and the knowledge available on the physical factors influencing the physical, chemical, and biological processes involved in WWT. Then, decision on whether to choose it or not can be taken on a variety of considerations. They are summarized in Table 21B.

Table 21B: Socio-economic and Institutional Criteria for Selecting WWT Options

| Criteria for choosing a technology option for wastewater treatment | Overall Socio-economic Condition | | | | | |
|---|---|---|---|---|---|---|
| | Land-rich[1] | | | Land-scarce | | |
| | City including metro | Small town | | City including metro | Small town | |
| | | Urbanized | Less urbanized | | Urbanized | Less urbanized |
| Land area for treatment | | | | | | |
| Crop production potential of WW | | | | | | |
| Fish production potential of WW | | | | | | |
| Degree of sophistication | | | | | | |
| Capital cost of the system | | | | | | |
| O & M requirement | | | | | | |

Source: based on authors' own analysis

[1] Land-richness does not mean that land is cheap. It is decided by the population density. Cities with low population density are considered as land-rich and those with very high population density are considered as land-scarce. Land-scarce urban areas will eventually rule out the possibility of having WWT systems that require reasonable amount of land.

**Note**: WWT systems that require a lot of land like WSP, and anaerobic ponds. It is understood that in highly urbanized towns, the price of land would be very high. Presence of agricultural areas, which are facing water shortage, would increase the economic viability of wastewater treatment systems, as there could be opportunities for trading with the reusable wastewater for irrigation.

## 8.2 Improving Water Use Efficiency in Urban Areas

### 8.2.1 Technologies

#### Waterless Toilets

Waterless toilets use no water for flushing and require only small amounts of water for cleaning. Therefore waterless toilets are an effective sanitation technology for the saving of water resources in the urban and domestic environment. The most common types are pre-composting, composting and dehydration toilets, based on dehydration and composting processes (Incinerator toilets are a special kind of toilet which is not environmental sound because they are energy intensive. They use electricity or gas to produce high temperatures for the burning of the faecal matter. Furthermore the faecal matter cannot be reused.

Therefore only dry toilets based on dehydration and composting processes will be further discussed). These toilet systems provide the ideal environment for pathogen destruction in human waste through dehydration and/or decomposition. The resulting inoffensive compost-like material can be applied to the soil to increase the organic matter content, improve water-holding capacity and increase the availability of nutrients.

The available systems vary from simple toilets with temporarily storage of excreta to enhanced toilet systems with on-site treatment. The human waste is stored in watertight-sealed and well-ventilated containers and is converted in a compost-like material. The final product should be odour free and have a soil-like consistency if the process has been correctly managed. In some systems only a pre-composting process takes place in the sealed chamber of the toilet. In these cases the matter is transported for the finalization of the composting process to an adequate facility. Maintaining the right level of humidity is crucial for an appropriate dehydration and composting process. Therefore, dry toilet systems often provide also the possibility of urine separation. For the Indian market dry toilets have also been developed to allow the separation of faeces as well as the separated draining of urine and anal cleansing water to allow an enhanced treatment process of the faeces.

The conditions under which they are most suitable are: 1] when water resources are scarce; income is very low; 2] no centralized water supply is available; 3] sewers and sewage treatment facilities are not present; 4] areas for the use of faeces and urine are available; 5] acceptance by the users as well as appropriate maintenance and service can be guaranteed; and 6] citizens are used to dry toilets already; and appropriate individual and community-based operation and maintenance exists (UNEP, 2008).

## Water-saving toilets (Low Volume Flush Toilets)

Water-saving toilets are based on the same working principles as common flush toilets, but they require a comparably low flush volume. Some of these toilets are also available with separated drainage for urine to reduce the impacts of nutrients and pharmaceuticals on the sewage receiving environment and to facilitate the reuse of the urine as a fertilizer. However, most water-saving toilets available on the markets are designed for the combined drainage of urine and faeces. They can be differentiated in toilets with low volume cisterns (including vacuum toilets), dual-flush cisterns and cisterns with water-saving retrofit devices. *Low-volume toilets* typically use 6 litres of water per flush, but there are also toilets available which require only 4 litres or even only 1 litre per flush. Cooley *et al.* (2010) use a figure of 1.6 gallons per flush, i.e., for their estimates of water saving through efficient devices in urban areas of US cities. They are available in designs which look similar as high-volume toilets which require approximately 10 litres per flush or even more (UNEP, 2008).

There are three types of low flush toilets: gravity tank toilets, flushometer toilets and vacuum toilets. While gravity tank toilets flush based on the gravity flow of water, flushometer toilets require a minimum water pressure for the flush (provided by pressure in piped water supply). The transport of faeces in both systems is provided by gravity flow in sewer pipelines after flushing. Vacuum toilets require only a very small amount of water which is actually not used as transport media but as a slip additive. After flushing the transport of faeces is provided by a vacuum which is created by a vacuum station connected to a collection tank at the end of the sewer pipeline (UNEP, 2008).

They are ideal when: central water supply and a connection to a sewage treatment facility are available; the installation of dry toilets is not feasible; new installations of water-saving toilets are feasible if new toilet installations or if the replacement of old toilets is required; the flushometer technology can only be applied in areas where a relatively constant and comparably high water pressure from piped water supply is available, which cannot be guaranteed in many developing countries; the installation of retrofit devices is appropriate if existing high-volume toilets have to be optimized for low cost and in short term; water-saving is simultaneously stimulated by education, water metering and pricing (UNEP, 2008).

### Water-saving low head showers

Water-saving shower heads, or low-volume showerheads, improve water use efficiency compared with high-volume shower heads by mixing water with air, improving the spray patterns or by creating a narrower spray that simulates the feeling of much water with low-volume flows. A variety of spray and other design options are available for new low-volume showerheads. For the retrofitting of conventional high-volume showerheads flow restrictors can be installed[19].

Shower heads using flow control devices can be used to adjust the flow rates, independent of the water pressure. The function is generally based on a disc containing an elastic O-ring that is controlled by pressure. Under high pressure the O-ring flattens and reduces the water flow while it relaxes and allows higher flow under lower pressure. Additional water-saving devices, mainly applied in public buildings to avoid water losses, are metered-valve taps, delivering a preset amount of water before shutting automatically off. Self-closing spring-loaded taps feature a knob that automatically shuts off the water when the user releases the knob. They are appropriate when the installed shower heads are meeting the comfort criteria of the user; or water has to be saved without changing behaviour pattern and without loss of comfort (UNEP, 2008).

### Pressure Reducers

Pressure reducers can be installed either at the supply point of a building or at certain points inside a building in case of larger or higher buildings. Pressure reducers are installed between pipeline joints to reduce the water pressure and to reduce the flow to taps and other fixtures. The technology is appropriate when Buildings are equipped with a centralized water supply; and the water pressure in the whole building or in building parts is high (above 3 $kg/cm^2$) (UNEP, 2008). Table 22 gives details of conditions under which these four technologies are appropriate, and the type of urban situations for which they are most suitable.

[19] These are inexpensive plastic or metal disks with a small hole in the middle. They are inserted in the coupling between shower arm and hose and fit to standard connections. However the flow rate cannot be adjusted exactly with these devices because the specific flow rate also depends on the water pressure.

Table 22: Water Saving Technologies in Urban Domestic Sector

| Type of technology | Features | Conditions Under which it is appropriate | Type of urban situations for which it is most suitable | | | |
|---|---|---|---|---|---|---|
| | | | Poor urban neighbour-hoods | Rich urban neighbour-hoods | New settlement | Tall housing stocks |
| Waterless toilet | Cost ranges from Euro 8 to Euro 50<br><br>Waste has to be transported mechanically | When water shortage is acute; income is low; sewage disposal facility not available; area for use of faeces and urine are available | *** | | *** | |
| Water-saving toilets | Three types: gravity type; flushometer type and vacuum type | System is connected to a treatment facility; pressurized water supply required for flushometer to work; water is metered & priced volumetrically | | *** | | |
| Low head showers | Inexpensive; retrofitting is possible | When water has to be saved without loss of comfort; or without changing the behavioural patterns | | *** | *** | |
| Pressure reducers | Easy to install; needed for every floor of the building | Used when the water supply is centralized and pressure is very high (> 3 bar) | | | | *** |

### 8.2.2 Creating Incentives for Efficient Water Use Technologies

They should be encouraged in cities/towns where the cost of production of water (opportunity cost of water production) is very high. In absolute terms, the technologies for efficient use of water would make sense when the marginal cost of reducing wastage is less than the marginal opportunity cost of producing that much of resource. It should be kept in mind that the marginal cost of improving WUE would increase exponentially at higher levels of efficiency, and hence should be encouraged only if the cost of producing and supplying water to maintain such levels of use is high.

In very water-scarce regions, efficient water use technologies could be subsidized, as they might help reduce a lot of social costs that could be accrued by creating new water sources and generating additional waste. In any case, the private benefit due to water-saving should exceed the private costs the users would be confronted with as a result of use of the EWU technologies. This private benefit is nothing but the reduced water charge.

## 8.3 Main System Improvement Measures

In this section, we would discuss leakage detection technologies and engineering measure for leakage prevention based on the knowledge generated through engineering research conducted in many parts of the world on water supply systems. It would also discuss the indirect benefits of leakage prevention such as hydraulic efficiency improvements. But, prior to this, it would also discuss how urban growth pattern could affect physical performance of water supply system, mainly the losses in pipelines. We would also present some case studies on leakage prevention and UFW reduction measures. The economics of UFW reduction is also discussed.

### 8.3.1 Growth Patterns within Urban Areas and their Impact on Water Losses

All water systems leak. They leak both through pipes and at joints. Depending on their condition, drinking water systems can lose 6 to 25 per cent or more of their water through leaks and breaks[20]. Two major factors determining leakage are length and system pressure. Longer systems leak more than shorter ones; systems that operate at higher pressures leak more than systems that operate at lower pressures. Systems in low-density areas must use higher pressures to push water through longer mains. Because low-density areas tend to have higher demand for water for lawns, water pressures must be increased even more during dry months (IWSA, 1991). Lot size has a greater effect on water system costs than how isolated a site is or how far it is from the water service centre (UNEPA, 2006).

Depending on their condition, water systems lose 6 to 25 per cent of their water through leaks and breaks (Levin *et al*., 2002).

The form of development affects water use. Development that is more spread out—less dense—needs a longer system than development that is more compact. Therefore, in general, water systems in less dense developments will leak more than systems in compact developments. The analysis provided in Section 10.5.6 shows that greater the geographical area of the city, higher the percentage unaccounted for water. Of course, if the central pumping station is located on the urban fringe, nearby low-density users will not generate as much loss as their more distant counterparts in other parts of the metropolitan area. Nonetheless, highly dispersed communities will need longer systems and incur greater loss

[20] In 1995, water systems in the United States leaked 25.3 billion gallons of water per day.

overall than would more compact communities, regardless of where the main pumping system is located (UNEPA, 2006).

Leaks are a financial burden for drinking water systems, imposing costs that are ultimately borne by ratepayers or, if the system is subsidized, taxpayers. In some cases, curbing large water losses from leaks can save a town or district the cost of finding additional water sources. Since 1989, the Kansas Rural Water Authority had completed 564 water loss surveys locating an annual loss of 2.387 billion gallons (Kenny, 1999). The annual costs to purchase or produce this loss would have been $3.586 million. Also, it is found that large plots increase water demand as the demand for water to water loans etc, would be more.

According to an enquiry in 1991 by International Water Supply Association, around 20-30 per cent of the water supplied from treatment plants is lost in transit before it reaches the consumer (Cheong, 1991). In the case of typically older systems, the losses could be as high as 40-50 per cent (AWWA, 1987).

One of the critical elements of main system improvement measures is the detection and prevention of leakages. The other is detection of illegal tapping of water from the mains and sub-mains. The third is the improvement in the hydraulic efficiency of the network. They are all discussed in the subsequent section with examples from India, Canada and Japan.

### 8.3.2 Leakage Prevention System

The system of leakage prevention in pipes include: corrective measures: leakage detection and repair; preventive measures: replacement of old pipe material by new pipe material (replacement of caste iron pipe by ductile cast iron pipe; lead pipe by stainless steel pipe); and, technical development for leakage prevention (introduction of new technology for leakage detection, new materials for water distribution and services etc.

#### Leak Detection in Pipes

There are two steps in a systematic leakage control programme: 1] water audit; and 2] leakage detection survey. Water audit can be done in two ways depending on the situation that exists. In case, the connections in a water district are metered, then audit become easy. The total amount of water used up at the end user level can be volumetrically measured for a stipulated time period (say one week); and the total amount of inflow into the water system can also be monitored. The difference would give the total amount of water lost in conveyance--unaccounted for water (which include un-accounted for losses and technical losses).

In the second case, when connections are not metered, the water distribution system is divided into different zones, and flow is allowed into only one zone or district (with a trunk line length of 20-30 km) by turning off the valves in other distribution lines. Flow meters can be installed at control points. Water flow into the district is measured over a 24-hour period, with measurements taken during night time and day time. The minimum flow rate during night time is compared against the average day-time flow rate to estimate the percentage un-accounted for water. Here, the assumption is that the minimum flow rate during night time is due to the leakage alone, when no one uses the water from the tap.

Leak detection survey can be undertaken for different stretches of the main or distribution pipeline. Acoustic leak detection is normally employed. It has two phases: 1] an initial survey is conducted by listening leak sounds using high frequency listening devices; and 2] a detailed precision survey is undertaken at suspected leak locations using ground microphones at points above the pipelines at intervals of 1.5metres. However, such leak detection surveys are effective for metallic pipes. Their effectiveness for plastic pipes which are increasingly used for water distribution is questionable.

Leak noise correlators can be used to detect leaks in plastic pipes. Leak noise correlators are portable computer based devices with onboard data acquisition and analysis components. It works by measuring the vibration (vibration censors) or sound (hydrophones) signals at two points that bracket the location of the suspected leak.

But, research in Ottawa, Canada which evaluated a number of leak detection equipments (on the methods on which they are based) showed that leak noise correlators are effective when the surveyors measured the actual sound propagation velocity in the pipe and used the correlators, with appropriate filer setting. Vibration censors were effective in detecting large leaks (20l/min). Hydrophones had to be used to detect small leaks (6l/min). But, the listening equipments were not effective unless listening censors or devices were used at access points that were close to leak sources. Noise correlators are more efficient and give more accurate results than the ordinary ground-based sound listening equipments. But, as Tokyo experience shows, leakage detection by acoustic methods became extremely difficult due to the increase of city noise, traffic density, and congestion of buried structures. In such cases, electro-magnetic detectors or tracer gases will have to be used.

## Technology Development for Leak Detection

The Bureau of Water Works in Tokyo established an Office of Leakage Prevention in 1974 to cope with the machinery for prevention of leakage and to the study and development of leakage prevention technology. Therefore, development of new leakage search technology which was not influenced by the difficult work environment, (i.e., was easy to operate,) and that made work more efficient, was necessary. They established a "Training and Technical Development center" to plan the reinforcement of the development system and the general improvement of waterworks technology and to carry out the technology development that could cope with a change of on-site needs immediately. Table 23A summarizes the main technology and machinery concerned with prevention leakage which were developed and improved.

Table 23A: List of technologies used for Leakage Detection in Pipes

| Apparatus | Content |
|---|---|
| Electric leakage detector | Picks up leakage noise electrically on ground surface |
| Freezing method | This method keeps the water inside the pipe frozen with liquid air during repairs |
| Portable minimum flow meter | This flow meter is used at the minimum night flow measurement |
| Correlation type leakage detector (Leakage Noise Correlators) | This instrument locates the leakage by processing leakage noise picked up at two point on pipe |
| Underground radars | This radar radiates electro-magnetic wave to ground so as to search the underground condition |
| Time integral type leakage detector | Making use of the continuity of leakage noise, this instrument is able to check whether the leakage exists or not |
| Non-metal pipe locator | Making use of the transmission noise, this instrument can locate the non- metal pipe |
| Helium gas leakage detector for buried pipes | Detect leak points despite surrounding noises |

| | |
|---|---|
| Electro-magnetic leakage detector | Identifies a spot of leakage by detecting fluctuations of reflected electromagnetic waves in accordance with the movement of leaking water |

Source: the Bureau of Water Works, Tokyo Metropolitan Government

## Leakage Prevention and Hydraulic Efficiency Improvement

The escalating cost of construction and power; high level of waste making the service more expensive in one end; the enormous concentration of population causing strain to the existing infrastructure, posing serious problem of the basic health of the population on the other end cause, all make the building of new infrastructure very expensive. The increase or expansion of the existing capacity of the present system to cope with the growing demand is in no way economical in terms of optimal use of finance and resource.

As per some reports, in India, the cost of water losses amounts to US$ 16 million per year. If we consider the cost of production of water as Rs. 2.1 per cubic metre on the basis of figures derived from the data for 301 cities and towns in India, the total volume of water lost works out to be 380 MCM. This is around 35 litres of water per day per capita in urban water supply systems. The distribution grid/pipe lines are one of the major contributors to this loss. It is only recently realized that in order to run a water supply system efficiently more attention to be paid to improvement in hydraulic efficiency of the pipelines as well as rehabilitation of the old systems and the reduction of water losses. This not only helps in augmentation of supply within the existing capacity, but also makes production and supply of water cheaper.

Major improvements in an existing water supply may be obtained by cleaning the mains, identifying the corroded sections, leaky points and repairs the same. In some situations the old pipe lines need replacement/rehabilitation due to reduction of their hydraulic efficiency or for their structural deficiency.

Generally, the Department goes for spot repairing of the leaky places even for very old mains just to maintain the supply and have little scope to consider the long term benefit of the method. The huge loss of water through leaky points physically exposed are well appreciated by the authority but the huge hidden loss of power going every seconds to transmit water through an old main due to increased frictional resistance are generally overlooked or kept uncared for. The reduction of carrying capacity of the pipeline is caused due to effect of deposition and corrosion of the main.

The frictional coefficient 'C' may vary from 140/150 for smooth pipe to 40 to 50 for badly tuberculated pipe. Head capacity curve drawn for a 24" diameter pipe 5000 ft. long for varying 'C' value of 140, 105, and 70 well shows the difference in flow due to the increase in pressure loss (Table 23B).

Table 23B: Maximum Discharge Possible with Different Friction Coefficients in Pipes under Different Head Losses

| Loss of Head (m) | Discharge in MG for different values of "C" | | |
|---|---|---|---|
| | 140 | 100 | 70 |
| 13.50 | 10.00 | 7.0 | 5.0 |
| 23.20 | 15.00 | 10.0 | 7.0 |
| 49.30 | 20.00 | 15.0 | 10.0 |

Source: Tarit Kumar Mukhopadhyay, the Calcutta Municipal Corporation, Calcutta, India

From the above result, it is observed that if the 'C' value decrease 50%, then the force required to pump the same quantity of water increases by 3.16 times. This indicates the need to take adequate steps to main the 'C' value as far as practicable for the overall economy of the system. Rehabilitation of the main to recover the 'C' value or regain its structural strength may be a way but major constraint is the high investment. However, the cost benefit analysis in terms of life cycle cost of the main to be calculated to check up the viability of the project. The rehabilitation of the water supply mains offers benefit of various quantifiable and non-quantifiable kinds.

The major ones are:

- Positive impacts on health of the consumer
- Long term benefit resulting from the strengthening/ replacement of weak pipe sections and repair works
- Optimum use of the existing infrastructure and deferring the immediate investment
- Improved relation between consumers and supply authorities
- Curtailment of maintenance expenses of the pavement and less interruption of traffic system.
- Less incidence of damage to other services
- Update and complete existing drawings
- Benefit through the sale of more water

## Measures for Leakage Prevention and Hydraulic Efficiency Improvement: Tokyo Experience

<u>Introduction of a simple work method in 1964</u>: It took for 4-7 years to make a round of all water supply areas by a method applied in the leakage prevention plan operation in 1962. In this way we could prevent a leakage, but, because of the repetition phenomenon of leakage in the meantime, leakage prevention was ineffective. Therefore, the utility shifted to a simple work method which omitted the measurement of leakage volume. From 1964, we adopted an acoustic method mainly and we proposed to promote the efficiency so as to make a round of all water supply area in about 2 years. By introduction of this simple work, work efficiency rose remarkably at first, but, as we omitted the measurement of leakage volume in this method, grasp of leakage volume was impossible and there was not an aim for a worker. As a result we realized the importance of the leakage volume measurement in workers' motivation.

<u>Introduction of a block water meter in 1970:</u> In addition to a simple work method, Tokyo water carried out the work that took in leakage volume measurement work from 1970. This method paid attention to the time period when there was no water usage in a block at night. First, gate valves surrounding the block to be investigated were closed and the water from other blocks was shut down. Then the water was sent into the block through minimum flow measuring equipment set in the block water meter and the flow rate was measured. The minimum flow rate measured during the vacant period was considered to be the leakage. To measure the smallest flow quantity, the sizes of the blocks was reduced to around a quarter of their previous size and divided the ward into 3,600 blocks and we carried out setting a block water meter in 1978 from 1970.

<u>Introduction of ductile cast iron pipes:</u> With respect to distribution pipes, cast iron pipe was mainly used since the modern water supply system was established. As the domestic cast iron pipe production ability was low in those days, cast iron pipe made in foreign countries were used. After that, since 1960, a ductile iron pipe having about 3 times the

strength of a cast iron pipe was adopted in large diameter distribution pipes (1000 -1500 φ). Later on, the diameter range for application of this method was expanded and used it as the main material for all distribution pipes. As a result, the number of leakage repairs in distribution pipes decreased greatly. In addition, in 1978, a seismic coupling pipe with a restraint mechanism in the coupling was adopted on the distribution pipes, with diameter more than 400mm and a seismic coupling pipe was adopted after 1998 in response to lessons learned in the great Hanshin Awaji earthquake disaster which occurred in 1995.

Adoption of stainless steel pipes in service lines: Stainless steel pipes provide corrosion resistance, long life and strength As maximum leakage was found in the service pipes on public roads (as against, private roads and land for housing) the lead pipes were replaced by stainless steel pipes there. This resulted in drastic reduction in the number of cases of leakage in service pipes from 35000 to about 2500 in a time span of 20 years (1985-2005). As percentage of steel pipes in the service pipes increased from zero to 100 during the 20 year time period, the leakage decreased from 15 per cent to 4.4 per cent.

#### Encasing and Jacketing for Rehabilitation of Old Pipelines: Kolkatta Experience

In Calcutta, in the 70's rehabilitation of 45", 60", 54" and 72" M.S. leaky main was done by way of encasing the same with 9" thick R.C.C. without disturbing the supply. But, of late it is found that the water is coming out and could not able to provide the main leak proof. On the other hand it has become an impossible task to locate the actual position of the damage of the steel main. The rehabilitation of another stretch of 72" M.S. main was done by way of jacketing with M.S. plate inside the main, welding the plates with mother steel main and finished with painting inside the epoxy based resin. Though the internal diameter of the main gets reduced in jacketing, it was found to be working satisfactorily. The main hindrance in jacketing is that it needs the portion of the main out of commission.

In late '80s, 100m of an old 45" riveted main has been rehabilitated, as pilot project, by way of outside jacketing with 100mm thick plate, First the leaky spots are plugged and welded with small thin plates and then 10mm plate rolled to pipe of 1.5m long each with inside diameter 1" higher than the outside diameter of the existing pipe placed over it in two halves and jointed by welding longitudinally and circumferentially. The outside surface of the plate is painted with anti-corrosive paints. The inter space between the outside of old main and the inner side of the newly rolled pipe fixed are grouted with cement.

The above process has given the structural strength and plugged up the leaks of the main. But the major hindrance of this method are: 1] extensive damage of the existing road surfaces; 2] damage to other utilities situated close by; 3] hindrances to the flow of traffic; 4] Tendency of deflecting of the running main due to removal of bed and again supported on newly filled up excavated soil; and 5] No improvement of inner surface i.e. 'C' value.

It has been noticed that the old main plates has tendency to tear out from riveted circumferential joints due to deflection and subsequently welded but it is exposing a risk of bursting. In metropolitan city area this method has been found not to be very favourable, however, the work could be carried out without disturbing the City supply. Recently 100 and 150 mm dia. C.I. main laid in 19th Century were rehabilitated by withdrawing, cleaning and relaying in the same alignment/trench. During relaying process about 30% new pipe were used and the supply in that area has been improved considerably.

### 8.3.3 Reduction of UFW in Two Indian Cities

There are two types of losses: 1] physical (technical) losses due to leakages; and 2] administrative losses (non-technical or unaccounted) losses. The following cases explain how the UFW, which includes both technical losses and administrative losses, were brought down in two major Indian cities, viz., Hyderabad and Bangalore.

## Hyderabad

The HMWSSB commissioned study on *Water Conservation, Leakage Control and Use Management* study carried out by TCE found that 14 per cent of the water was lost to physical leakages in the transmission system and 140 litres per connection per hour at 10 meters pressure were lost in the distribution **syste**m. Administrative losses were estimated at 12 per cent. The Board initiated a four year program in 1995, implemented with World Bank support that aims to reduce leakages in the transmission system to five percent, losses in the distribution system to 10 litres per connection per hour at 10 meters pressure, and administrative losses to four per cent (source: USAID, 2000).

The interventions included: setting up bulk meters for measuring the production volume and losses in the transmission lines, and tapping points and service connection pipes; setting up leak detection equipments; and repair of joints for reducing leak. From 1996 to 1998, the Board repaired 474 of 615 leaks identified on 408 kilometres of transmission main. It is repairing the remaining leaks on the transmission system by caulking joints with lead, steel collars, cement, and chemical sealants (source: USAID, 2000).

The study determined that nearly 70 per cent of the estimated loss in the distribution system was from leaks at tapping points and in service connection pipes. Reasons included that the water authority did not own the consumer connections and meters; pipe material and service tap materials were substandard; and distribution main and service connections were not mapped properly. The utility is replacing all old, damaged leaking pipes and service connection pipes (source: USAID, 2000).

The main causes of administrative losses, the study found, were that 82 per cent of domestic meters and 92 per cent of bulk consumer meters were not working. So, the Board installed 60,000 new domestic meters, 590 non-domestic and 126 bulk consumer meters from 1996 through 1998. In addition, the board announced a general amnesty in 1996 and regularized more than 6,000 illegal connections by levying a small penalty. Other remedial measures included training staff on leak detection equipment and surveys, system mapping, creating consumer data, and repairing leak detection equipment. The Board also conducted an extensive public education program on water use and conservation. As a result of all these measures, the Board estimated that UFW in the entire system has been reduced by approximately eight percent. Unaccounted for Water (UFW) is different from unaccounted losses. The first is the sum of technical losses and non-technical losses (USAID, 2000).

Engineering research carried out in Queensland, Australia shows that when the level of leakage reduction increases or in other words when the leakage (expressed in litres per connection per hour) is reduced, the cost for leakage reduction increase exponentially. The Economic Target Leakage corresponds to that rate of leakage where the cost of reducing the leakage to that level would be equal to the cost of that leakage. Reducing leakage beyond this point will not make economic sense. The cost of leakage reduction increased from 0.0 at 7.5 litres of leakage per connection per hour to about US $ 20 for 2.5 litres per connection per hour, when the cost of the water leaked per connection decreased from 6.5 US $ to 3.0 US $ (Montgomery Watson, 2000).

## Bangalore

BWSSB has taken up a pilot project on UFW reduction and the estimated cost of the works is about Rs 480 million. In addition to CWSSB Stage, Phase, JBIC has also funded this project, specifically valves, meters and leak detectors, and the consulting services as technical assistance. The description of the work is given in Table 24A.

Table 24A: Details of UFW Reduction work carried out in Bangalore City by BWSSB

| Particulars | Pilot Area | Bangalore total |
|---|---|---|
| Population | 4.0 lac | 48.4 lac |
| Water supply volume | 70 MLD | 850 MLD |
| No. Of Connections | 32,000 | 380,000 |
| Length of main line | 302 km | |

The work comprises establishment of District Meter Areas (DMAs) within the pilot area for the purpose of monitoring of UFW and detection of leakage, provide bulk meters to measure water consumption at DMA level, inspection of all consumer meters, fixing of new meters on unmetered water connections or on connections where meters are not working, testing of meters for accuracy, recording of consumptions on revenue meter to measure water supplied to the consumers. The difference between the input into DMA and water supplied to consumers is the total loss of water in the DMA. Based on these inputs, decide permissible loss to get target levels and carryout leak detection survey, identify leaks, repair leaks and retest the DMA till loss of water is reduced to target leakage level (Tsuchiya, 2004).

Also, carryout condition assessment survey of water distribution network in the DMA / pilot area and rehabilitate water pipelines prone to leaks. Work also includes renewals/replacement of service connections using MDPE pipes wherever necessary. DMA is established with boundary valves which make DMA hydraulically isolated and limit inflow/outflow points of DMA. At limited inflow/outflow points, district meter will be installed to measure inflow volume of DMA accurately. UFW can be calculated as shown below (Tsuchiya, 2004).

UFW = [Inflow to DMA] – [Consumption in DMA (billed amount)]

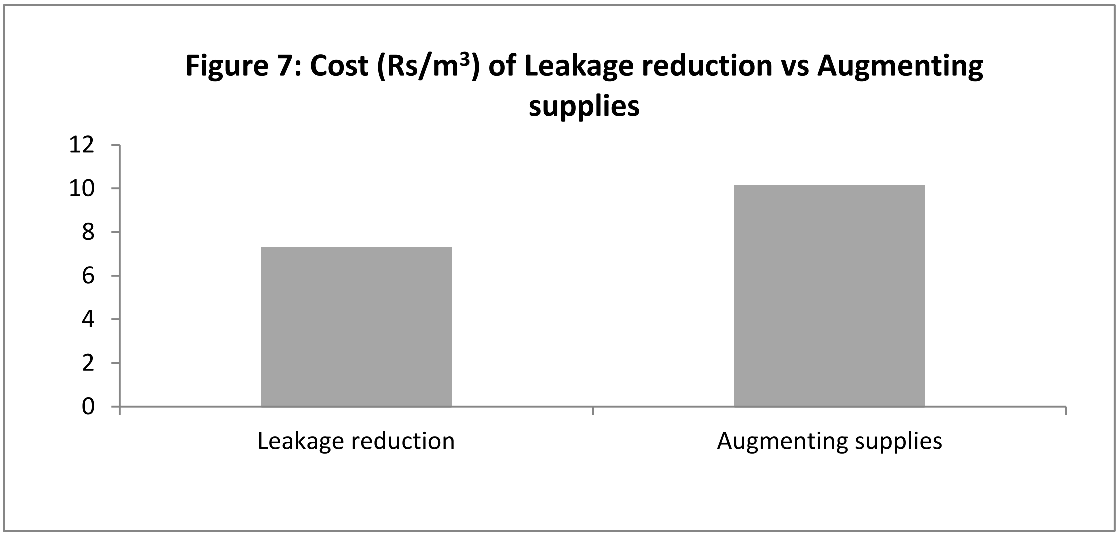
Design of DMA shall be done with the aid of computer network models, high level model covering the project area and low level models for each DMA to ensure and demonstrate that the proposed DMA establishment works will be able to maintain adequate hydraulic capacity of the DMA under 24 hours satisfied demand conditions as well as ensuring no unacceptable detrimental impact on supplies to areas adjacent to the DMA. The boundary of the DMA shall be watertight. Circulating valves, i.e. those valves that are closed in order to remove all loops from within the DMA thus producing a tree-like mains layout, shall be identified and new valves installed where necessary, which will make leakage detection works more easily and efficiently. The size and extent of areas within the DMA that can be progressively isolated in order to identify leakage levels across the DMA shall be determined to minimize the need for step valves commensurate with best step-testing practice. New step valves shall be installed where necessary (Tsuchiya, 2004).

Progress of the project is about 60% as of the end of May. 2004. The current result is encouraging. In progressed DMA (DMA-3A), UFW has been reduced down to 53% of initial volume. Besides in DMA-1, UFW has been reduced down to 54%. And in DMA-3C, UFW has been reduced down to 70%. The status of the project is based on the data prepared by BWSSB and its consultant team (Tsuchiya, 2004).

### 8.3.4 Economics of UFW Reduction

Based on the experience of Bangalore, it can be said that to take up a UFW reduction project, it would cost somewhere near Rs. 1200 per capita in a city of similar population density (4800 lac/4 lac=1200). It is reported that nearly 45% of the water supply in Bangalore city was lost as UFW (ADB, 2007). When we consider a per capita supply level of 74 litres per day at the end user level, and further assume that UFW is reduced by half through the prevention measures (Tsuchiya, 2004), the per capita water supply saved works out to be 30 litres per day. If we make a realistic assumption that the investment lasts for 40 years, then the cost per cubic metre of saved water works out to be Rs. 7.27 per $m^3$ of water. This was estimated using a discount rate of 6 per cent for the capital expenditure (NPVA=0.0664). This is far less than the actual cost of production and supply of water in Bangalore, which is Rs. 10.12 per cubic metre (ADB, 2007). The estimates are graphically represented in Figure 7.

What is more important than this simple comparison is that the cost of production of water does not include the resource cost and environmental costs of depletion of water resources. In water-scarce conditions this would be very high. But, in the case of leakage prevention measures, both are avoided. Hence, this is economically and environmentally




more sound than investing in a new water augmentation system in a situation like that of Bangalore.

### 8.3.5 Where do we do Leakage Reduction Measures?

We have seen in Section 8.3.1 that leakage is a function of the urban population density and geographical area. Leakage reduction measures, introduced in any urban area, will have to be economically viable, meaning the average cost of saving every unit of water through leakage prevention measures will have to be less than the average cost of production and supply of water. Economic viability therefore depends on the cost of leakage prevention measure. It is to be kept in mind here that while the cost of leakage reduction is a function of the degree of reduction in leakage, the unit cost is not constant. Low degree of reduction in the leakage could be achieved with minimum unit costs (Montgomery Watson, 2000), and for higher degrees of reduction in leakage, the unit cost would go up exponentially. Hence, what determines the cost of leakage reduction is the level to which the leakage is to be brought down, rather than the degree of reduction. Because of this, the unit cost of leakage reduction will be lower in situations where the leakage is very high currently.

Here, the unit cost of leakage prevention, corresponding to reduction of pipeline leakage to a certain level, would again be an inverse function of the area covered. This is because of the fact that when same volume of water is supplied to a small area, the amount of engineering infrastructure required to do leak proofing would be comparatively less. Therefore, the first step is to assess the extent of leakage in pipeline network. Table 24B shows the matrix of various considerations involved in deciding on leakage reduction measures in an urban area.

Table 24B: Socio-economic and Institutional Criteria for Deciding on Leakage Prevention

| Criteria for Selecting a network for Leakage Reduction Programme | Overall physical, socio-economic and political set up | | | | | |
|---|---|---|---|---|---|---|
| | Water-scarce | | | Water rich | | |
| | Cities including metro | Small towns | | Cities including metro | Small town | |
| | | Urbanized | Less urbanized | | Urbanized | Less urbanized |
| Unit Cost of production | | | | | | |
| Cost of leakage reduction | | | | | | |
| Staff training | | | | | | |

Source: based on authors' own analysis

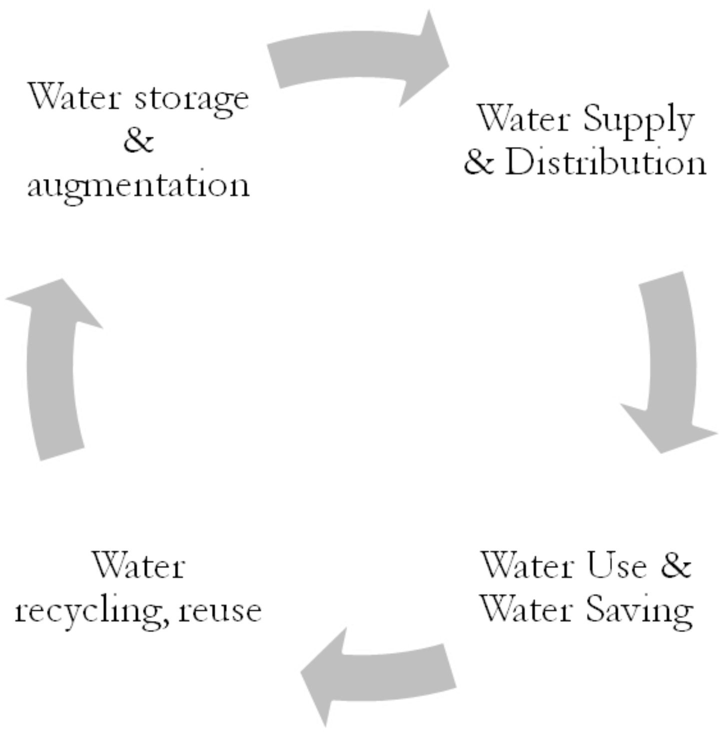
What the matrix shows is that in a water-rich area, first the cost of production & supply of water against the cost of leakage reduction has to be ascertained whereas the same is not required in a water-scarce area. Leakage reduction programme should be taken up only after ascertaining that the required skilled manpower is available for carrying out the programme.

## 9.0 URBAN WATER SUPPLY SYSTEM PLANNING

### 9.1 Generating Data on Urban Water

Constructing the *natural water balance* of the urban area is crucial to assessing the water availability. The next challenge is to relate this balance to the higher level of the (river) basin. This implies making an analysis of the natural input and output in annual averages. The second step is an analysis of the patterns of rainfall and evapo-transpiration and of the other ingoing and outgoing flows (primary infiltration and runoff). They can be measured, for instance, in monthly averages. Sometimes, the seasonal pattern is most relevant, but in other cases the diurnal rhythm matters, as in the case of potential dew harvesting. Peak events have their own rhythm given in the return periods of 10 or 100 years. The third step is to analyze and compare the actual water use hydrology: residential and industrial water use, the discharge of wastewater and storm water run-off. Although not strictly urban, agricultural water use, usually the biggest water consumer, cannot be left out from the balance, especially not at the river basin level. A comparison of the water use hydrology (Figure 7) with the natural water balance may result in a better understanding of the problems and opportunities for storage and augmentation in the long run (UNEP, 2008).

Figure 7: Urban Water Use Hydrology

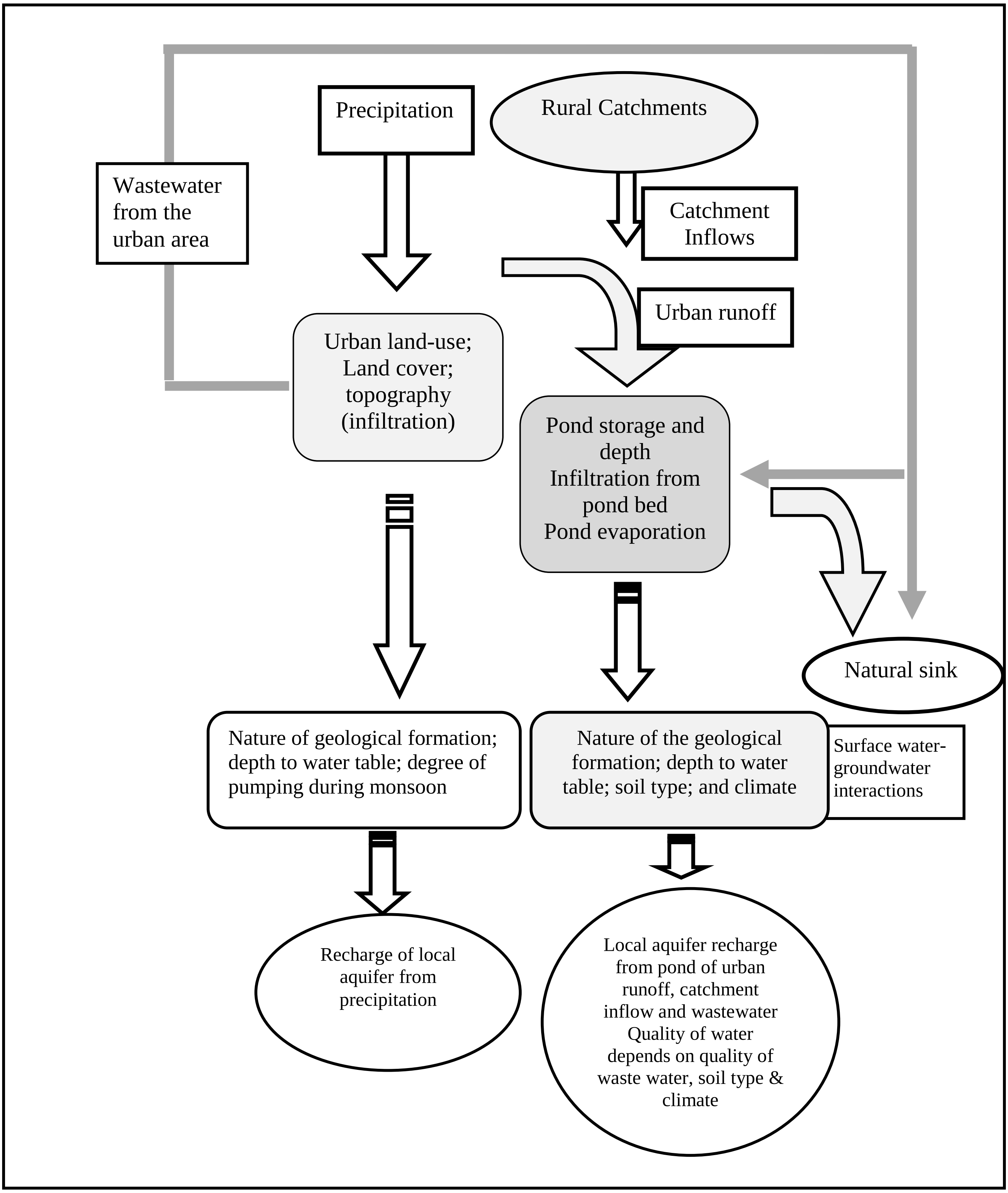



### 9.1.1 Data on Water Resource Availability

Water resource availability for meeting urban water needs is a function of quantity and quality of water. Generating data on urban water resources in terms of quantity and quality is the key to urban water management planning. A comprehensive and integrated understanding of urban hydrology is important for urban water management planning. Urban hydrology is very complex with runoff from natural catchments such as that of lakes, ponds, rivers/rivulets; runoff from artificial catchments such as built up area and pavements (storm water); groundwater; and wastewater outflows. They also interact among each other. The storm water flows can contribute to the stream flows into rivers, lakes and ponds. The amount of storm water generated is a function of the rainfall (magnitude, intensity and pattern) and the land cover. Hence, changes in land use (increasing built up area, pavements, etc.) can increase the storm water flows, and potentially threaten the ecosystems by increasing the sediment load, and water temperature etc.

A typical flow diagram for analyzing the urban water cycle is presented in presented in Figure 8.

Figure 8: A Flow Diagram Showing Urban Water Cycle




The amount of renewable groundwater and its stock (static groundwater) in an urban area is determined by the nature of geology. Regions with alluvial geology have better groundwater stock. They also have high natural replenishment, whereas regions with hard rock geology have extremely limited groundwater potential due to poor specific yield values.

This is evident from the table which shows the renewable groundwater recharge per unit area of land for all the districts of India.

Certain localized phenomena can change the groundwater availability at the micro level significantly. Some of them are presence of water bodies, which can induce prolonged recharge unlike other areas where the recharge occurs only during monsoon months. The others are mountainous terrain conditions which can increase the outflows from the aquifer into natural streams due to the steep gradients available. Hence, in the first case, the additional recharge after monsoon needs to be evaluated and considered as part of the total recharge to groundwater. In the second case, the outflow during the non-monsoon period needs to be evaluated and deducted from the total annual recharge.

But, the change in land use can potentially change the local groundwater recharge occurring during rainfall in an urban area through reduction in the infiltration area, though recent studies show that the reduction in infiltration area can be compensated by the greater amount of recharge from natural impoundments in the urban area. Further increase in harvesting of roof catchment runoff can reduce the storm water outflows. Increase in use of water in the urban areas would result in increased wastewater generation.

Wastewater can be an important source of water for urban areas if properly managed. If treated to safe limits, this can augment the existing sources of water supplies (Marsden Jacob, 2007). But, if the wastewater goes back into the natural water system untreated, it can threaten the hydrological integrity of the existing sources. The wastewater can flow into the lakes, ponds and rivers and the quality of the resulting water would be determined by the quality and quantity of the receiving water as well as that of the wastewater.

The wastewater can also percolate down to the groundwater systems. The percolation would increase with increase in hydraulic loading; reduce with increase in depth to water table (vadoze zone) and increase with increase in hydraulic conductivity of the geological strata. In areas with shallow water table, and permeable soils and higher hydraulic loading, the deep percolation rate would be higher and faster. The amendments in the quality of waste water, which can happen during its vertical movement, would be determined by the depth of the vadoze zone; soil structure and texture; the climate (temperature and humidity); and the soil moisture conditions (see Section 7.1.1 for details).

In the light of the foregoing discussions, the following data need to be generated for analyzing water resources.

1. Catchment characteristics: to estimate the rainfall-runoff relationships

2. The annual rainfalls for several years, particularly for locations that are falling in low to medium rainfall regions to arrive at the stream flows in different years

3. The location of various water bodies, their storage features and pond infiltration rates: to estimate the additional (lake) recharge potential

4. The depth to water table and the pre and post monsoon fluctuations: to estimate the natural recharge to groundwater during rainy season

5. The land use and land cover of the urban area, including the roof area and characteristics, to estimate the storm water generation potential

6. The urban drainage pattern

7. The outflows of wastewater, and the rate of wastewater generation, the quality of wastewater and level of assimilation due to mixing up with streams and water bodies.

8. Infiltration rates from river/lake/tank beds. This can be assumed as 1.4mm/day for surface water bodies (GOI, 2005 as cited in Chatterjee and Ram Purohit, 2009).

9. The geo-hydrological parameters (depth to water table, soil structure and hydraulic conductivity) that govern the degree of treatment of wastewater achieved before reaching the aquifer (see Table 26)

The unique typologies that are possible in India and the type of surface water-groundwater interactions possible under each typology are given in Table 25:

Table 25: Type of Groundwater-Surface Water Interaction Possible under Different Typologies

| Type of Formation/ Geo-hydrology | Deep water table conditions | Shallow water table condition | | Coastal Areas | |
|---|---|---|---|---|---|
| | | No pumping | Round the year pumping | No pumping | Pumping |
| Consolidated | Weak surface water-groundwater link | Recharge limited to the short period of monsoon and stops after steep rise in WT | Recharge is continuous throughout the year[2] | Groundwater outflow to sea to maintain hydrostatic balance | Maintain the groundwater balance and check movement of seawater. Intrusion will be faster with increase in porosity, and presence of caverns |
| Semi consolidated--sandstone, limestone | Weak surface water-groundwater link | Continuous recharge during the whole year | Do | Do | |
| Unconsolidated | No recharge; [1] | Continuous recharge during the whole year | Do | Do | |

Source: based on authors' own analysis

1. Water gets held up as hygroscopic water. Alluvial areas with deep water table conditions are found in semi arid and arid regions.

2. The recharge rate depends on the location of the pumping wells. To maintain high recharge rates, it is necessary that the pumping well is kept close to the recharge mount which is created owing to the water body.

Table 26: Degrees of treatment possible for municipal wastewater under different typologies

| Water Table Condition | Heavy soils, humid to sub-humid climate | Heavy soils, arid to semi arid climate | Light soils, arid to semi arid climate | Light soils; humid to sub-humid climate | Hard rock geology; with fissures and cracks exposed to the surface |
|---|---|---|---|---|---|

<table>
<tr><td>Deep water table</td><td>Does not exist</td><td>High degree of treatment (biochemical & bacteriological)</td><td>High degree of treatment</td><td></td><td rowspan="2">Low level of bio-chemical purification; no bacteria & virus removal</td></tr>
<tr><td>Shallow Water Table</td><td>Reasonable level of bio-chemical treatment; poor bacteriological purification</td><td>Reasonable level of bio-chemical and bacteriological purification</td><td>Low level of bio-chemical treatment; low level of bacteriological purification</td><td>Low level of bio-chemical treatment; no bacteria and virus removal</td></tr>
<tr><td>Outcrop areas of deep aquifer</td><td>Low level of bio-chemical treatment; no bacteria & virus removal</td><td>Low level of bio-chemical treatment; reasonable level of bacteria and virus removal</td><td>Very low level of bio-chemical treatment; poor removal of bacteria & virus</td><td>Very low level of bio-chemical treatment; no bacteria removal</td><td>Not applicable</td></tr>
</table>

Source: based on authors' own analysis

Note: Heavy soils are those with high clay content. Light soils have poor clay content. Bio-chemical treatment here refers to reduction in BOD and COD. Arid to semi arid climate ensure hot and dry conditions, whereas cold and humid to sub-humid conditions ensures cold & moist conditions.

### Criteria for Hydrological Monitoring

The water level monitoring should involve dense network of wells in hard rock areas with shallow water table and coastal areas, with many located in the vicinity of lakes and ponds. This is in view of the strong surface water-groundwater interactions and the drastic variations in water level fluctuations possible with hard rocks. In alluvial areas, the network of wells can be very sparse. In humid and sub-humid areas (with shallow water table conditions), the water quality monitoring should focus on BOD/COD and bacterial count. The monitoring should be more intense in outcrop areas of deep confined aquifers (alluvial). In deep water table areas (arid and semi arid), since the chances of bio-chemical and bacteriological contamination are extremely low.

### 9.1.2 Data on Water Quality

In urban water management, water quality monitoring (WQM) is of paramount important in order to make sure that: people in the urban areas get water of adequate quality; and also the quality of the natural sink into which the wastewater is disposed, is not adversely affected to cause undesirable effects on the water ecosystem and the uses that they cater to. The earlier one is crucial because many of the water-related health problems occur in human populations due to absence of good quality water for drinking, and most of the positive developmental outcomes of providing water supplies can be nullified by poor quality of the water. The latter is crucial because the water from natural sink might find its way into the underlying aquifers which communities in the urban peripheries or rural areas might tap for human consumption without prior treatment; or communities might use the natural sink for fishing or irrigating crops. While the water quality norms might be more stringent in the first case, it will be more relaxed in the second case, as direct human consumption would require water of much higher quality as compared to that used for uses such as irrigation and wild life and fisheries.

The quality criteria for water used for different purposes by Bureau of Indian Standards are given in Table 27.

Table 27: Quality criteria for water used for different purposes

| Designated best use | Class of Water | Criteria |
|---|---|---|
| Drinking water source without conventional treatment but after disinfection | A | Total Coliforms Organism MPN/100ml shall be 50 or less<br>pH between 6.5 and 8.5<br>DO 6mg/l or more<br>BOD 5 days 20oC, 2mg/l or less |
| Outdoor bathing | B | Total Coliforms Organism MPN/100ml shall be 500 or less<br>pH between 6.5 and 8.5<br>DO 5mg/l or more<br>BOD 5 days 20oC 3mg/l or less |
| Drinking water source after conventional treatment and disinfection | C | Total Coliforms Organism MPN/100ml shall be 5000 or less<br>pH between 6 to 9 DO 4mg/l or more<br>BOD 5 days 20oC, 3mg/l or less |
| Propagation of wild life and fisheries | D | pH between 6.5 to 8.5<br>Dissolved Oxygen 4mg/l or more<br>Free Ammonia (as N) 1.2 mg/l or less |
| Irrigation, industrial cooling, controlled waste disposal | E | pH between 6.0 to 8.5<br>Electrical Conductivity at 25oC micro mhos/cm Max.2250<br>Sodium absorption Ratio Max. 26<br>Boron Max. 2mg/l |

Surface water from natural catchments[21] is of much better quality than groundwater in India. Here, the water quality is assessed in-terms of physiochemical, and bacteriological properties. The groundwater in many regions in the country is found to be containing several physical, chemical, biological impurities (Kumar and Shah, 2004). While some of them are naturally occurring, some of them are occurring due to pollution from external environment.

There are a large number of water quality parameters (27 of them) which groundwater has to be tested for before it is declared "safe" for human consumption. But, testing of water samples for some of these chemical constituents such as heavy metals, pesticide and fertilizer residues, fluoride and arsenic is prohibitively expensive whereas testing for certain other chemical parameters such as nitrites/nitrate, TDS, calcium,

[21] The urban catchments should be excluded from this.

magnesium, total hardness and chlorides is less expensive. There are certain regions which are reported to have chemicals present in groundwater occurring in natural conditions.

For instance, the incidence of fluoride above permissible levels of 1.5ppm occur in 14 Indian states, namely, Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal affecting a total of 69 districts, according to some estimates. Some other estimates find that 65 per cent of India's villages are exposed to fluoride risk (Kumar and Shah, 2004).

High levels of salinity are reported from all these states except West Bengal and also the NCT of Delhi, and affects 73 districts and three blocks of Delhi. Iron content above permissible level of 0.3 ppm is found in 23 districts from 4 states, namely, Bihar, Rajasthan, Tripura and West Bengal and coastal Orissa and parts of Agartala valley in Tripura (Kumar and Shah, 2004).

High levels of arsenic above the permissible levels of 50 parts per billion (ppb) are found in the alluvial plains of Ganges covering six districts of West Bengal. Presence of heavy metals in groundwater is found in 40 districts from 13 states, viz., Andhra Pradesh, Assam, Bihar, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, and five blocks of Delhi (Kumar and Shah, 2004).

In such situations, it is quite essential to develop typologies of urban areas in terms of groundwater quality problems found. This would help us save the precious resources needed to monitor the groundwater periodically for ensuring its safety. For instance, the problems of fluoride and TDS in groundwater are not encountered in north eastern states. Hence, there is no need to include these parameters in water quality testing in the states of eastern India. Arsenic problem has so far been encountered only in the Gangetic plains of West Bengal. So, this needs to be included in WQM only for cities falling in that region.

In addition to the inherent quality problems, water quality monitoring needs to capture groundwater pollution. The pollutants include: bio-chemical pollution (BOD, COD, TDS, nitrite, nitrate, heavy metals such as Chromium, Cobalt, Mercury, Lead; Copper and Cadmium, and fertilizer and pesticide residues). But, the current monitoring covers only TDS, BOD/COD, pH, nitrate and nitrite, ammonia, and total & faecal coliform. Heavy metals are totally left out from the chemical analysis (source: based on CPCB, 2008).

The Central Pollution Control Board (CPCB) has established a network of monitoring stations on rivers across the country. The monitoring is done on monthly or quarterly basis in surface waters and on half yearly basis in case of ground water. The monitoring network covers 250 Rivers, 78 Lakes, 6 Tanks, 26 Ponds, 8 Creeks, 19 Canals, 19 Drains and 382 Wells. Among the 1245 stations, 695 are on rivers, 86 on lakes, 19 on drains, 19 on canals,6 on tank, 26 on pond (a total of 851 for surface water), 12 on creeks/seawater and 382 are groundwater stations. Water samples are being analyzed for 28 parameters consisting of physiochemical and bacteriological parameters for ambient water samples apart from the field observations. Besides this, 9 trace metals and 28 pesticides are analyzed in selected samples. Bio-monitoring is also carried out on specific locations. In view of limited resources, limited numbers of organic pollution related parameters are chosen for frequent monitoring i.e. monthly or quarterly and major cations, anions, other inorganic ions and micro pollutants (Toxic Metals & POP's) are analyzed once in a year to keep a track of water quality over large period of time (CPCB, 2008).

As is evident from the foregoing discussions, the density of groundwater quality monitoring network is extremely poor given the large number of towns, cities which are dependent on groundwater and the large number of potentially polluting sources in their vicinity.

## Designing Water Quality Monitoring Network

Water quality monitoring is an expensive business. It is impossible to monitor groundwater in all the towns and cities for all water quality parameters given the magnitude of work and the resources needed. Therefore, it is important to identify: the pockets which are most vulnerable to groundwater pollution; the pockets that have polluting industries; and pockets having low ecosystem carrying capacity. This will help in doing optimizing the cost of WQM.

The factors which determine the degree of vulnerability are: the aquifer type (whether phreatic or confined); depth to water table; soil texture and structure; humidity; temperature; rainfall; and the presence of structures that impound polluted water. The degree of vulnerability would be higher in phreatic aquifers (both in alluvial and hard rock geology) with shallow water table with sandy soils and outcrop areas of deep confined aquifers. The cold and humid climate compounded by heavy rainfall would increase chances of biochemical and bacteriological contamination due to the effect of "flushing". If the polluted water is collected in natural storages, that would increase the opportunity time, hydraulic load and hence the rate of infiltration and total percolation. Further, in hard rock areas, due to the formation of a cone of impression below the natural storage, the hydraulic connectivity gets established between the polluting water source and the receiving groundwater. Table 28 provides a matrix for determining the degree of aquifer vulnerability to pollution under different physical environments.

Given the vulnerability, the type of pollution of groundwater from effluents (municipal and industrial) depend on the type of urban area--whether industrialized, or trade centre with no industries or peri-urban. In heavily industrialized urban centres, chances of heavy metal contamination of groundwater are likely to be high. In small towns (as found in the case of Mulbagal, Suryapet and Bheemavaram) and peri urban areas, the likelihood of pesticide and fertilizer contamination is high, owing to the fact that agricultural land is common within the administrative boundaries of urban centres. Heavy metal contamination is likely to be high in groundwater underlying landfill sites. Monitoring of heavy metals would be required in large cities with large landfill sites because of human health risk involved. The risk would increase if ideal environment (such as shallow groundwater table, high rainfall, permeable soils and humidity) prevails. However, it may not be required for small towns, particularly those having no industries. For instance, the groundwater quality monitoring carried out by Arghyam-Indian Institute of Science in Mulbagal town of Kolar district in Karnataka did not show any trace of heavy metals in groundwater.

The degree of groundwater and surface water pollution would depend not only on the quantity and quality of effluents, but also on the quantity and quality of the receiving surface water body, which together determines the degree of assimilation of pollution possible before it starts percolating down to the aquifer and finally gets reflected in the quality of the receiving water body.

This has great implications for framing pollution control policies. The logical basis for setting the limits to discharge of pollutants into an ecosystem--river, wetlands, and estuary--is the carrying capacity i.e., the amount of an individual pollutant that can be safely assimilated by that specific ecosystem. Hence regulators of industrial pollution are moving towards a carrying capacity based regime which will decide the limits—discharge standards—that can be let into a specific ecosystem through programs such as total maximum daily load1 (TMDL) in US and integrated pollution prevention and control (IPPC) in EU.

Because of this reason, an ecosystem carrying capacity-based approach to water quality monitoring should be adopted rather than using a uniform standard for effluent discharge (Rajaram and Das, 2008). In a region with abundant surface water flows like the eastern Gangetic basin (eastern UP, Bihar, West Bengal), the norms for effluent discharge will be much less stringent than in a region which is facing environmental water scarcity like the basins of western India, and peninsular India excluding Godavari.

The data available from Central Pollution Control Board shows the level of pollution of surface water in major Indian River basins (CPCB, 2008). Hence, in regions with high rainfall and substantial stream flows or abundant surface water in lakes/ponds, even heavy effluent disposal will not pose much threat to groundwater in terms of pollution.

Hence, three factors need to be considered while deciding on the number of parameters for which water quality monitoring needs to be undertaken: history of water quality problems (the natural water quality problems existing in an area); the degree of vulnerability of the urban area to groundwater pollution; and the type of urban area; and the final quality of the effluent-receiving water.

Table 28: Degree of vulnerability of aquifers to groundwater pollution

| Type of aquifer/Soils, rainfall | Hard rock strata; low to medium rainfall | Hard rock strata; high rainfall | Heavy alluvial soils, low to medium rainfall | Heavy alluvial soils; high rainfall | Light alluvial soils; low to medium rainfall | Light alluvial soil; high rainfall |
|---|---|---|---|---|---|---|
| Unconfined aquifers with shallow WT | Medium vulnerability[22] | High vulnerability | High vulnerability | Very high vulnerability | Very high vulnerability | Highest degree of vulnerability |
| Unconfined aquifer with deep WT | Low vulnerability | Does not exist | Very low vulnerability | Does not exist | Low vulnerability | Does not exist |
| Confined aquifer | Does not exist | Does not exist | Not vulnerable | Not vulnerable | Not vulnerable | Not vulnerable |
| Outcrop area of confined aquifers | Do | Does not exist | High vulnerability | Very high vulnerability | Very high vulnerability | Highest degree of vulnerability |

Source: based on authors' own analysis

Note: In India, confined aquifers are found only in alluvial basins. As a result, there are no outcrop areas encountered in hard rock aquifers. The hard rock aquifers include basalt and crystalline rocks.

A close look at the groundwater monitoring stations maintained by the Central Pollution Control Board (838 nos.) shows that very few of them are located in the industrial effluent and municipal waste discharge areas, which are sources of "point pollution", which have very high hydraulic loading and high residence time for polluted water. Also, the density of observation wells is precariously low when compared to international standards. In fact, many of the observation wells are located in rural areas which have non-point pollution, and as a result the pollution effect is likely to be diffused. The observed levels of water quality are not likely to reflect the extent of groundwater pollution occurring in urban centres. In sum, it is reasonable to conclude that the current monitoring of groundwater pollution in India is inadequate to capture the extent of groundwater pollution occurring both in terms of the magnitude and extent of pollution and the pollutants.

[22] There could be short-circuiting in case of deep fractures and fissures that are exposed on the surface increasing the vulnerability in both the first and second case.

The important conclusion emerging from the analysis is that: 1] pollution vulnerability should be an important consideration in deciding on the density of monitoring network in a region; 2] following the same set of parameters for pollution monitoring won't make much sense, and instead the type of parameters should be decided by the history of groundwater quality problems, and the nature of polluting sources; and 3] for the same level of pollution load, the degree of pollution of water body would be an inverse function of the ecosystem carrying capacity. This also means that following a uniform standard for effluent discharge will not be effective in controlling pollution, and the standard should be set by the ecosystem carrying capacity.

Considering the fact that any water quality monitoring programme has to be cost effective and based on ecosystem carrying capacity, the type of essential water quality parameters for which groundwater needs to be monitored in different typologies were identified and summarized in Table 29. While doing this, we have kept in mind the reported incidence of groundwater quality problems in various parts of the country, the degree of vulnerability of different typologies to groundwater pollution.

Table 29: Essential Water Quality Parameters for Monitoring in Different Urban Typologies

| Typology No | Socio-economic Characteristics | | |
|---|---|---|---|
| | Large industrial cities | Small industrial towns | Small non-industrial towns |
| 1. | Fluorides, TDS, heavy metals | Fluoride, TDS, heavy metals | Fluoride, TDS |
| 2. | Nitrate, TDS, Heavy metals | Nitrates, TDS, Heavy metals | Nitrate, TDS |
| 3. | Arsenic, Fluoride, Nitrate, BOD, pH, Iron, heavy metals | Arsenic, Fluoride, Nitrate, BOD, pH, Iron, heavy metals | Arsenic, Nitrate, BOD, pH, Iron |
| 4. | TDS, BOD, Arsenic, Nitrates, Iron, heavy metals | TDS, BOD, Arsenic, Iron, Nitrate, Heavy metals | TDS, BOD, Arsenic, Iron, Nitrate |
| 5. | TDS, Fluoride, Iron | TDS, Fluoride, Iron | TDS, Fluoride, Iron |
| 6. | BOD, Nitrate, Iron | BOD, Nitrate, Iron | BOD, Nitrate |
| 7. | | | |
| 8. | TDS, pH, Fluoride | TDS, pH, Fluoride | TDS, pH, Fluoride |
| 9. | TDS, Fluoride, pH, Heavy metals, | TDS, Fluoride, pH, Heavy metals | TDS, Fluoride, pH |
| 10. | BOD, Nitrates, Heavy metals | BOD, Nitrates, Heavy metals | BOD, Nitrates |
| 11. | TDS, Fluorides, Heavy metals | TDS, Fluoride, Heavy metals | TDS, Fluorides |
| 12. | Iron | Iron | Iron |
| 13. | Heavy metals, TDS, Fluorides | Heavy metals, TDS, Fluorides | TDS, Fluorides |
| 14. | Fluoride, TDS | Fluoride, TDS | Fluoride, TDS |
| 15 | Nitrate, BOD, pH, heavy metals | Nitrates, BOD, pH, Heavy metals | Nitrate, BOD, pH |
| 16 | TDS, Chloride, pH, Heavy metals | TDS, Chloride, pH, Heavy metals | TDS, Chloride, pH |

Source: based on authors' own analysis

Note: The inherent chemicals found in groundwater are: fluorides, nitrates, nitrites nd chlorides

## 9.2 Planning Tools for Urban Water Supply

### 9.2.1 Why Do We Need IUWM Planning?

For generating comprehensive knowledge about the benefits and dis-benefits of the many tools and systems which fall under the banner of integrated urban water management, many knowledge gaps need to be filled in. The following comments about knowledge gaps and research needs relates to the *integration* aspect of IUWM rather than its constituent components.

#### Knowledge gap about infrastructure cost saving

According to Coombes and Kuczera (2002), infrastructure cost savings will only be realized if water authorities downsize or defer augmentation of centralized infrastructure to account for lower system burden achieved by implementing IUWM approaches. At the present time, water authorities are not sufficiently confident of the long-term changes in system performance and operation and maintenance costs resulting from the operationalising of IUWM concepts. One such concept will be integrated operation of local groundwater system, lakes and tanks and a distant large reservoir for supplying water to an urban area. The normal tendency of the urban utilities is to tap only one source, if it is capable to meeting all the demand, instead tapping multiple sources.

One reason is that perhaps, they aware of the experiences of other utilities, such as energy, which have not been able to realize the projected reductions in the end use. Also, they are unforthcoming of diverging very far from the traditional infrastructure planning practice. The reason is that they are risk adverse, and are conscious of the difficulties of enlarging buried infrastructure, such as pipes, once they are constructed. Further research into the changes in system behaviour, and therefore, the changes in design, operation and maintenance requirements, is required to change this situation. This will require rigorous systems performance monitoring and analysis as well as tracking, reporting on operational and maintenance regimes (including costs) and broad dissemination of the findings.

#### Knowledge Gaps about Outcomes & Impacts of Experiments

There is often a lack of knowledge about the extent to which the systems implemented in the case study sites achieved their original water servicing project goals. Another knowledge gap is how best to integrate cutting-edge technologies into existing infrastructure systems. Little work has occurred in the area of "retrofitting" existing systems beyond desk-top studies and water authority wide water conservation programmes (encouraging the installation of efficient water fixtures and appliances and rainwater tanks and grey water systems). Tapping the potential of more strategically focused retrofit and/or replacement programmes, collectively considering allotment, street scale and regional infrastructure would require greater attention, given the combined forces of the aging of the existing infrastructure and the push to increase population densities within established urban areas. [23]

The non-structural techniques for storm water management are likely to play a greater role in retrofit situations than green field and redevelopment sites. However, the efficacy of non-structural techniques is not well understood.

In response to this lack of understanding of the role of non-structural storm water quality best management practices, the CRC for Catchment Hydrology has been working in the area of non-structural storm water management for some years and has recently produced a number of reports that are available from their web site. Sydney Water has also been conducting research on the impact of a range of technologies retrofitted within existing Sydney suburbs, especially in the area of water conservation and efficiency.

Research into the acceptability of source control and prevention at source measures, particularly those that require behavioural change of individuals is also required, as this area is poorly understood, but may be required for certain IUWM options to be successfully implemented, particularly within existing urban areas. It is the author's view that policies of increased urban densities have been endorsed in many cases without due reference to the consequence on existing water systems. This is somewhat indicative of the fact that, to date, the relationship between urban water and land use planning has received little attention from policy makers or researchers. Water service provision needs to be added to the traditional equation that includes components such as transport, energy, housing and employment, to provide a holistic approach to urban planning and sustainable development.

Source: Mitchell, Grace V (2004) Integrated Urban Water Management: Australian Practices, CSIRO, Australian Water Resources Association.

## Extending IUWM Concept into Urban Planning

There is significant scope to extend the concept of IUWM into the arena of integrated urban planning. In fact, to make significant gains, it appears necessary as evident from the enormous analyses provided in this report. For instance, analyses of data for 301 towns and cities provided in this report have shown that vertically growing cities will be able to provide water supplies with lesser manpower and lesser cost; sewerage system at lesser cost; and cities with well laid out streets with sufficient clear space will be able to provide efficient solid waste disposal; cities with smaller geographical area and with higher population density will be able to implement leakage reduction measures cost effectively.

In the words of Niemczynowicz (1999): "New integrated system solutions based on sustainability criteria must be introduced already at the level of long-term regional physical planning guide all subsequent detailed planning and implementation. Such solutions should be put into practice in the construction of urban areas and their infrastructure." The need for policy and planning frameworks and the opportunities within the planning hierarchy were discussed by Mouritz et al (2003), while a water sensitive planning guideline has recently been produced for the Sydney region, which also contains a water sensitive toolbox (Mitchell, 2004).

We need to be careful that we are not just shifting the environmental, social and/or economic dis-benefits of urban water management services in either time or space. That is,

[23] The work of the former NSW departments of Land and Water Conservation and Public Works and Services (the former is now part of the Department of Infrastructure, Planning and Natural Resources and the later is part of the Department of Commerce) on integrated urban water planning in non-metropolitan urban areas is a good start in this area.

the dis-benefits should not be simply shifted to a new location, such as from a local surface water body to a distant groundwater system, or delayed in time, such as form an immediate negative impact to a slow building but long-term impact. The lack of a commonly agreed, robust, assessment tool that could be used to evaluate the merits of proposed alternative water servicing options, against environmental, social and economic criteria, considering short, medium and longer term time horizons is a key issue. Such a tool would enable issues such as a apportioning of developer charges and incentives, management of risk, end user and community acceptance and operational roles and responsibilities to be assessed in an agreed manner between developers and approval agencies (Mitchell, 2004).

There is considerable amount of research required in the area of public health, financial, political, environmental and technical risks. More broadly, there is a need for risk assessment frameworks that are designed for use within an IUWM assessment framework. Research into risk also should be linked to demonstration project monitoring programs, providing quantification of risk whenever practicable. It should also take a balanced view of the risks in the existing conventional system and the potential benefits of alternate systems. As Mitchell (2004) points out, "Taking an integrated view of the water supply, storm water and wastewater services should enable opportunities for conjunctive use of storm water and the various forms of wastewater. To date, there are few examples of this approach being incorporated into the system and when it has, technical and regulatory problems have been encountered. More work needs to be done in this area to overcome these obstacles and to create technologies and systems that provide opportunities to utilize both streams of water" (Mitchell, 2004).

### 9.2.2 Planning Tools for Urban Water Management

#### REALM

REALM (**RE**source **AL**location **M**odel) is a generalised simulation computer software package originally developed by the (former) Department of Conservation and Natural Resources (Victoria), Australia in close conjunction with the water industry. Since then, there had been many enhancements in response to the suggestions and feedback from the users. Currently, REALM is adopted as the modelling tool for use in water supply planning and management in Victoria. The states of Western Australia and South Australia are also major users of REALM (A latest version of REALM can be down-loaded free of charge from the Department of Sustainability and Environment (Victoria) website http: //www. dse.vic.gov.au/vro/water).

A comprehensive description of the model as well as its structure and configuration details related to urban water supply system modelling are presented below. Most of the following contents are extracted either from REALM User's Manual (Victoria University and Department of Sustainability and Environment 2005). REALM requires three main input data files; stream-flow file, demand file and system file. The stream-flow file contains the system inflow details and climatic data. System inflows are the unregulated stream-flow that is available for harvesting. Climatic data in the stream-flow file (e.g. temperature, rainfall, climatic indices) are used to model reservoir evaporation losses and seasonally adjusted monthly demands from the AAD forecast values. The demand file contains the unrestricted demands for each demand zone in the water supply system. REALM configures the actual system using a set of '*nodes*' connected by '*carriers*'. The system file contains the information on nodes and carriers in the network (e.g. capacity constraints, transfer priorities etc.) and long-term operating rules controlling inter-reservoir transfers and demand restrictions.

In urban water supply modelling, REALM can configure five types of nodes: 1] reservoir nodes which can explicitly model maximum capacity, dead storage, evaporation and reservoir inflow; 2] demand nodes to model urban supplies; 3] stream junction nodes to model river confluences which can have a stream inflow at the junction; 4] pipe junction nodes where two or more pipes meet; 5] stream terminator nodes to configure the terminating points of the water supply system.

The above nodes are connected by either river or pipe carriers. Both these carriers are distinguished by the way their capacities are modelled. The first type is the '*fixed capacity carrier'* with a constant monthly maximum capacity. The second type is a '*variable capacity carrier*', in which the capacity of the carrier is dependent on the values of one or several system variables. These carriers can explicitly model minimum flows, maximum capacities and transmission losses. In addition, by assigning a set of user-defined '*penalties*' (usually in the order of 0 to 1000) to the carriers, the preferred flow distribution of the water supply system can be modelled. When there are two or more flow paths between two nodes, flow will first occur in the carrier with the lowest penalty up to its capacity, then the carrier with the next higher penalty will be used and so on until the required flow is received by the downstream node.

REALM models the harvesting and bulk distribution of water resources within a water supply system. Similar to other simulation models, mass-balance accounting procedures are used at nodes, while the movement of water within carriers is subjected to capacity constraints. It uses fast network linear programming algorithm to optimise the water allocation within the system for each time step of a simulation period using user-defined penalties and operating rules. The operating rules are defined by restriction rule curves, target storage curves and other priority releases such as environmental flows. During each simulation time step, the model attempts to satisfy the following water assignment criteria (in decreasing order of priority) when allocating water within the system (Victoria University and Department of Sustainability and Environment 2005): 1] satisfy evaporation losses in the reservoirs; 2] satisfy transmission losses in carriers; 3] satisfy all demands (which may be restricted), to maximise supply reliability; 4] minimise spills from the system, to maximise the yield; 5] satisfy in-stream requirements defined by minimum capacity of carriers; and 6] ensure that the end-of-season storage volumes meet the reservoir targets.

The above water assignment criteria are achieved through the '*system penalties'* in REALM, which are several orders of magnitude greater than the user-defined penalties. These system penalties have in-built default values that cannot be changed by the user. However, any other operating rule contradicting the above hierarchy can also be modelled by using variable capacity carriers with very large positive or negative penalties. One such example as explained in Perera et al. (2003) is when it is required to meet the environmental flows before satisfying the urban (restricted) demands, which is contradictory to the REALM specified hierarchy of water assignment criteria mentioned above. This is achieved by turning off the minimum flow attribute of the carrier and creating a variable capacity carrier parallel to the above carrier, but with a capacity equal to the environmental flow and an appropriate large negative penalty.

New models and design methods for urban water cycle management are being developed by the Australian research industry. The Aquacycle model (Mitchell et al., 1997) allows the designer to understand daily water balances. The PURRS model operates at small time steps allowing understanding of the impact of decentralized approaches on the provision of urban water cycle infrastructure.

## MUSIC for Stormwater Management

Model for Urban Storm Water Improvement Conceptualization (MUSIC) used in Melbourne, Australia, was developed by the CRCCH as an industry capacity building initiative for advancing WSUD initiatives, and was first released in 2001 for beta testing by Melbourne Water, Brisbane City Council and associated consultants. MUSIC is a software modelling tool which allows for the creation of alternative concept designs for managing urban storm water, and for the benefits to be predicted, at a range of spatial and temporal scales. It was developed in response to the need for a more standardised and reliable approach by providing an agreed and uniform modelling basis for developers to demonstrate compliance with the urban storm water quality performance targets as outlined in the Best Practice Guidelines and the SEPP. The algorithms in the model were drawn from the previous 10 years of research, including the monitoring results from the Lynbrook project. The algorithms were regularly updated to capture research outcomes from the CRCCH and three versions of MUSIC have been released since 2000 at a nominal charge to industry. Melbourne Water supported the application of the MUSIC tool by industry, and released 'Guidelines for the use of MUSIC'28 recommending input parameters and specifying the types of program output for determining compliance with developer agreements (Brown and Clarke, 2007).

Thus the use of MUSIC significantly contributed to the more efficient uptake of WSUD principles and practices. Of note, over 230 people attended the Melbourne launch and seminar on MUSIC which was an unprecedented level of interest and support shown by the industry for a new software tool. Owing to this substantial interest, the software was subsequently presented in Sydney, Canberra, Brisbane and Adelaide attracting a total of 685 seminar participants around the country. The support from Melbourne Water and Brisbane City Council was recognised as instrumental in generating the strong industry adoption of the model (Brown and Clarke, 2007).

## 9.3 Modelling tools for Analyzing Water Resources and Services

### 9.3.1 Basin Modelling

Understanding physical interdependencies in water system is the first step towards implementing IWRM. The different factors affecting water availability such as catchments, stream flows in rivers and groundwater, base flows, return flows from various uses, are all hydraulically inter-connected at the level of the hydrological system, i.e., river basin. This means that basin should be the unit for analyzing the impacts of various interventions on any of the sub-components of the system on another, under IWRM approach in water management decision making.

Since, various demand sectors viz., urban water, agriculture, industry, rural drinking, and water for ecosystem services occur within the same basin, taking basin as the unit for analyzing demands can help assess the magnitude of inter-sectoral competition for water. Demand management tools such as water pricing and tradable property rights are crucial to improving urban water services which reduce inter-sectoral competition and conflicts, and are potentially consistent with an IWRM approach (Jønch-Clausen, 2001 and 2004; Rees, 2006). But, to assess the impact of these interventions on the overall water supply-demand scenario, and to assess the range of cross-sectoral assessments and actions which would be required, basin-wide analysis involving different sectors and sources is necessary.

The use of basin water demand & supply models can help analyze the nature of interaction between various components of the hydrological system. For instance, land use changes in the catchment will impact on the stream flows, increased groundwater withdrawal in upper catchment areas will impact on base flows downstream; surface water impoundments will impact on natural recharge to aquifers downstream. That means, if an urban water utility draws its supplies from the river, it should refer to the relevant catchment management strategy of the resource agency for information about the availability of water to support proposed plans; water quality requirements for the wastewater that is to be returned to the water resource after use; and the riparian rights of the downstream water users, while preparing its plans for meeting future targets. The modelling exercises could provide vital clues about what kind of institutional mechanisms is needed for better coordination between resource agencies and agencies that provide water-related services.

On the other hand, basin water supply-demand modelling can analyze the kind of interaction between different socio-economic systems that demand water and the potential impacts of change in the demand in one sector on the other. Therefore, it can provide indications on the kind of coordination required between urban water utility and the other sectors (agriculture, ecology, rural drinking & industry), which demand water from the basin[24]. Instituting water rights in rural areas might encourage farmers to transfer part of their water rights to urban areas for earning better income. Hence, this would also mean that adequate infrastructure for water transfer is built by the utility to meet its growing water demands.

One of the basin models which are used in analyzing such interactions is Water Evaluation and Planning System (WEAP) of the Stockholm Environment Institute, Boston. It has a supply program, a demand program and a network program. This decision support tool was used in Souk-Hras of Algeria in North Africa to analyze the water management options for the region under different scenarios. It was also used for analyzing the water management (supply and demand side) options for Sabarmati river basin in Gujarat under conditions of population growth, industrialization and urbanization[25].

Modelling of local aquifers can also be used to arrive at decisions regarding the safe levels of abstraction of groundwater in an urban area for long term sustainability of resource use. Such models can integrate considerations such as economically viable pumping depths, minimum permissible annual drawdown levels for preventing ecological damages such as saline intrusion, land subsidence etc. to provide outputs on optimal level of pumping. Such modelling exercises would immensely help in avoiding major ecological catastrophe as found in many Chinese cities and some Indian cities and land subsidence in the city of Bangkok. But, generating accurate data on geo-hydrological parameters and water levels would be crucial for proper calibration of such simulation models.

### 9.3.2 Modelling for Water Supply Systems

Some of the common problems associated with water supply systems are heavy leakages in transmission and distribution; and inadequate pressure at the end-user level. There are difficult to detect manually, manual detection is prohibitively expensive as often

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24 For instance, if urban wastewater meets streams, increased supply of water to urban areas to meet the growing demand would mean greater wastewater return flows and higher level of pollution of streams, posing a greater risk to the environment. This would call for additional investment for wastewater treatment infrastructure. This would call for greater coordination between urban water utility and the RBO, and pollution control board.

25 The basin has agriculture, industries, large urban centres, and commercial uses of water in large urban centres, including Ahmedabad metro. Depletion of groundwater, over-appropriation of surface flows, river pollution and conflicts over water use amongst different competitive use sectors are major issues. The Sabarmati River also experiences severe environmental water stress, due to excessive diversion of water for various competitive uses.

the exact layout of the old pipelines and the depth at which they are laid are not known. Hydraulic modelling of water supply system can also be used to identify the stretches of excessive water losses in the network; quantify pressure losses which are caused by improper design and aged-pipelines, and determine the alterations required in the system for improved performance. For calibration of such models with correct values of hydraulic parameters, it is important to do proper gauging of pressure, discharge and actual amount of tapping at key control points in the network. Such exercises were carried out in Bangalore city by Bangalore Water Supply and Sewerage Board under the pilot project on UFW reduction supported by JBIC. The most important hydraulic parameter is the roughness coefficient. The calibrated model can be run to detect the problems in the network (like illegal tapping, leakage) by comparing the observed values of key variable[26] with the model estimated values.

The mapping of the entire water supply system, including the supply sources & supply nodes, supply networks, and various tapping points and potential demand sites; and putting it on a GIS platform and superimposing it with the model estimated pressure and discharge values at control points would enable us to detect non-technical losses due to illegal tapping. Periodic observations of water levels in the aquifers underlying the city/towns, mapping them, and superimposing with the thematic layers earlier mentioned would help take some of the corrective measures on the resource side.

## 9.4 WEAP Modelling of Urban Water System

As we have seen earlier, WEAP simulation model has three distinct components: the supply programme; the demand programme and the network programme. Data on various water supply sources (aquifers, catchments inflows into rivers, local tanks, ponds, lakes and urban storm water) need to be fed into the "supply module". The data on all water demands and the factors controlling the demand (both per capita and aggregate) need to be fed into the "demand module". The data on the transmission losses (pipe leakage; losses during conveyance of water through canals etc. to the water distribution system) and the interaction between the demand site and the supply sources (link between demand site and WWT plants, flow of treated and untreated wastewater into the streams/lakes/ponds, the wastewater return flows into aquifer) need to be simulated by the network link. Based on these, the various inputs required for urban water management planning using WEAP are identified and presented in the Table 30.

Table 30: Inputs for WEAP and Hydraulic Modelling in Different Urban Typologies

| Sr. No | Nature of Urban Water Management Planning | Typologies for which it is applicable | Other characteristics |
|---|---|---|---|
| A | WEAP modelling inputs | | |
| 1 | Current population figures ward-wise | All typologies, except coastal ones | |
| 2 | Population projection data | Do | |
| 3 | Per capita domestic water use rates for each ward; and per capita water demand for different time horizons | Do | |
| 4 | Annual municipal water use other | Do | |

26 Pressure and discharge at control points.

| | | | |
|---|---|---|---|
| | than domestic | | |
| 5 | Irrigated area within the municipal limits, with the break-up of area under different crops; also the average depth of irrigation provided to the crops | All water-scarce typologies | Not important for metros with population more than a million |
| 6 | Physical, chemical and bacteriological quality of the municipal waste water | | |
| 7 | The points of disposal of the municipal wastewater and the approximate volumes: | All typologies | All towns/cities with centralized sewage collection system |
| 8 | Type of treatment viable for the area and the physical efficacy of the system | Do | Do |
| 9 | % households having decentralized sanitation system and the total amount of wastewater generated per day | Do | Humid, sub-humid regions with shallow WT |
| 10 | Sustainable groundwater yield | All typologies with hard-rocks & sandstone-alluvium+ all coastal typologies | |
| 11 | Urban drainage studies to examine changes in drainage pattern | All typologies except hilly & mountainous areas | |
| 12 | Total area of different catchments which form the source of water for tanks/lakes | Hard rock peninsular, central & eastern India which have tanks | |
| 13 | The annual rainfall figures for 30 years | All typologies | Rainfall intensity also (flood-prone area) |
| 14 | Rainfall-runoff relationships | All typologies, except the one with rainfall more than 1,800 mm | |
| 15 | Infiltration rates for lakes/other surface water bodies; daily evaporation rates | Hard rock peninsular, central & eastern India | |
| 16 | Total number of groundwater abstraction structures owned by municipality and individuals | All typologies | |
| 17 | Average groundwater utilization capacity of the wells | All typologies | Actual well yields and number of hours of running important for hard rock areas |
| **B** | Survey of water supply & sewerage infrastructure | | |
| 1 | Mapping of the water distribution and sewerage networks | All typologies | |

| | | | |
|---|---|---|---|
| 2 | Leakage detection survey | Networks older than 30 years | |
| **C** | Hydraulic Modelling | | |
| 1 | Measurement of pressure losses at key control points | Old networks | Towns/cities spread in large geographical area |
| 2 | Estimation of roughness coefficient of pipes | Do | |
| 3 | Detection of points of excessive leakage-water tapping | Do | Plus large cities; cities with low % connections |
| 4 | Water auditing | Do | Also in large networks where population density is low |
| 5 | Identification of stretches for remodelling, redesign etc. | Old networks | |

Source: based on authors' own analysis

## 10.0 CAPACITY BUILDING IN WATER SUPPLY AND WATER QUALITY

Capacity building is advocated by both practitioner and academicians for mobilizing institutional change. It spans a range of fields in different guises including public management (Grindle, 1997), collaborative planning (Healey, 1997), urban sustainability (Wakely, 1997) and development studies (Kaplan, 2000). While some commentators argue that the intangibility of the concept may make it 'stuff of myth or magic' (Harrow, 2001, p 210), others argue that it critically exposes development needs not immediately apparent (Grindle, 1997; Kaplan, 2000). While there is debate whether the object of capacity building should be to fill a 'deficit' or to 'empower' in some way, there does appear to be agreement that the design of capacity building interventions in practice are often too limited in their approach.

Capacity building in the water sector is a new concept that starts from three premises (Alaerts and Hartvelt, 1996): 1] water is a finite resource, for which numerous users compete, most notably the waste dischargers (who lower the usefulness of the water); 2] water is essential for a healthy economy as well as for the environment and, therefore, it is a resource that should be managed in a sustainable way; 3] institutional rather than technical factors cause weakness in the sector.

Capacity building should take a comprehensive look at the sector, analyses its physical and institutional characteristics in detail, defines opportunities and key constraints for sustainable development, and then selects a set of short- and long-term action programmes. Very often the water sector performs poorly because of inappropriate or rigid institutional arrangements. If these can be improved, structural constraints are removed. Capacity building should focus on strengthening the agency's ability to manage the demand for water on a sustainable basis, rather than augment the supplies through technological/engineering interventions.

### 10.1 Aims of Capacity Building in Water Supply Sector

Capacity building efforts have been typically implemented as training and education programs based on the idea that equipping individuals with new knowledge, skills and professional competencies will therefore enable them to successfully operationalise sustainable practices (Wakely, 1997). However, as observed by Wakely (1997) and Brown (2003), the organizational and broader institutional context presents as great an impediment to the sustainable management of urban places as the inability of professionals, technicians and ordinary people to operationalise sustainable development. Therefore, local government capacity for IUWM involving effective, efficient and responsive environmental governance is dependent on not only having sufficiently developed human resource capacity but also sufficient capacity within organizational and directive contexts (Wakely, 1997, UNDP, 1998; Peltenburg et al., 2000).

Through the Delft Declaration, the UNDP developed the following definitions of the aims of capacity building which are applicable for the water sector (Alaerts *et al.,* 1991): 1] creating an enabling environment with appropriate policy and legal frameworks; 2] Institutional development, including community participation; and 3] Human resources development and strengthening of managerial systems.

Experience, especially in developing countries and in economies in transition, shows that the main tasks ahead can be formulated as follows:

- Price setting, cost recovery and the enforcement of rules, are more difficult to implement than regulation (of water quality, for example) and, therefore, strategies to achieve these deserve priority.

- Inefficiencies can be addressed by allocating the right mandates and by reviewing the performance of the arrangement regularly. This will render organisations more alert and target-orientated. In rich as well as in poor countries, organisations must be orientated to the consumers of their "environmental services". In poor countries especially, engineers must be willing and able to co-operate with the community to facilitate O&M and cost recovery.

- Organisations must develop the right expertise profile.

Rebekah (2004) had described three mutually interactive spheres of capacity, which have well known capacity development interventions. However the relationships within and between these spheres is the key determinant of the resulting patterns of institutional practice. Change interventions focused on impacting any single sphere in isolation are insufficient without insightful assessment of existing capacity and respective development needs within the other spheres as part of a broader agenda for continually improving current capacity.

Effective human resource development through training and education initiatives is not possible without the enabling context of the organizational and institutional environments for effectively practicing newly developed understandings and skills (UNDP, 1998, Peltenburg *et al.*, 2000). Strengthening the organizational context through interventions such as catchment management arrangements are typically beyond the capacity of any single organization or network of organizations to continuously enact and therefore often depends upon directive support and incentives from state and/or national governments. However, effective directive reform needs to be critically informed by new organizational practices and advocacy for change from both individuals and organizations.

The various dimensions of capacity building are summarized in Table 31.

Table 31: Dimensions of Capacity Building

| Capacity Building | Description | Interventions |
|---|---|---|

| | | |
|---|---|---|
| Human resource development | Equipping individuals with the understanding, skills and access to information, knowledge and training that enables them to perform effectively | Recruitment, training |
| Organizational change | Elaboration of management structures, processes and procedures, not only within organizations but also the management of relationships between the different organizations and sectors (public, private and community). | Changing institutional structure; reporting systems; financial powers; funding |
| Directive reforms[1] | Making legal and regulatory changes to enable organizations, institutions and agencies at all levels and in all sectors to enhance their capacities. | Water pricing & water distribution policies, laws on protection of water sources, development of new institutions, prevention of water theft etc. |

Source: Brown, 2004

1 Typically termed 'institutional reform' however renamed here to avoid confusion with broader and/or different understandings of institutional (see Brown (2003, 2004) for an application of Scott's (1995) ideas on institutionalism).

## 10.2 Instruments for Capacity Building

1) Technical assistance for sector analysis and programme development: Since 1992, UNDP has developed "water sector assessments" which analyse comprehensively national water sectors and which develop a priority action programme. Other agencies, such as The World Bank and the Asian and European Development Banks, are also engaged in similar exercises. Such analyses need to be performed by an interdisciplinary team.

2) Technical assistance for institutional change: The expertise for this will differ depending on the institution that is under consideration and it may relate to policy, micro or macro-economic structures, management systems, and administrative arrangements.

3) Training for change at different levels, including decision-makers, senior staff and engineers with managerial assignments, junior staff and engineers with primarily executive tasks, technicians and operators, and other stakeholders (such as care-takers and people in local communities who have undertaken to operate or to manage community-based systems).

4) Education of prospective experts who will play a role in the sector: This encompasses physical and technological sciences, as well as financial and administrative management, and behavioural sciences. The water pollution control sub-sector is so complex and develops so fast that in most developing countries not more than 10 per cent of the required technical expertise (as university graduates) is

available. Many graduates are inadequately prepared for the tasks in their country (Alaerts, 1991).

## 10.3 Framework for Analyzing Institutional Capacity for IUWM

While different urban water contexts have variable institutional frameworks, peculiarities and capacity building needs it is important that a holistic assessment of the existing capacity for IUWM within the local management dynamic be conducted to systematically inform the design of capacity development programs. To assist with this assessment, the "factors" identified through the research undertaken by Brown (2004) as necessary for facilitating an IUWM approach provide a useful benchmark for determining to what degree capacities are currently developed and/or underdeveloped. The framework for analyzing the local management capacity of the existing institution for IUWM is provided in Table 32.

Table 32: Framework for Analyzing Local Management Capability of Existing Institutions for Urban Water Management

| Institutional Change Process | Formative Capacity Building Methods |
|---|---|
| Directive Reforms | • Incentives and disincentives for enabling intra and inter-organisational interaction<br>• Regulation of organisational capacity<br>• Mobilization of local political and community support<br>• MIS for benchmarking and reporting on organisational capacity |
| Organizational Strengthening | *Intra-Organisational Development*<br>• Corporate policy for sustainability<br>• Inter-departmental policy community<br>• Dedicated resources for waterway management<br>• Experience and competence with urban water management<br>*Inter-Organisational Development*<br>• Active cross-sectoral catchment stakeholder network<br>• Experienced in inter-agency collaboration and negotiation<br>• Valuing community participation and input |
| | *Skill Development*<br>• Environmental planning<br>• Group facilitation and negotiation<br>• Relationship building and networking<br>• Facilitating change management<br>*Basic Knowledge Development*<br>• Environmental resource management<br>• Sustainable development<br>• Urban water environment |

Source: based on Rebekah (2004)

## 10.4 Institutional Reform in Urban Water Supply Sector

### 10.4.1 Ongoing Reforms in Urban Sector having Relevance for Water

Current institutional reforms in urban water sector are happening under JNNURM, though in a very limited way. JNNURM aims at development of 63 mission cities (2 more added recently taking total number to 65), with focus on urban infrastructure, civic services, community participation and accountability of local governments, all as part of the decentralization of urban governance enshrined in the 74th Constitutional Amendment. The mission envisages investment of over Rs. 1 lac crore (over a seven year period starting 2005), of which Rs. 50,000 crore has been committed by the union government and the rest will be mobilized through state government funding and urban local bodies (ULBs). Till May 2009, 461 projects requiring an investment of Rs. 49,422.48 crore have been sanctioned. Nearly 74% of the sanctioned projects, aim at improving basic urban services such as water supply, sewerage, storm water drainage and solid waste management (MoUD, 2009). One of the special features of JNNURM is that funding support for infrastructure is linked to reforms i.e., cities need to enter into memorandum of association with Ministry of Urban Development to implement urban reforms in order to access JNNURM funds.

With particular reference to water supplies and sanitation, the urban areas in India require wide ranging reforms starting from water tariff reforms, introduction of resource tax, sewerage charges, pollution tax/stringent enforcement of pollution control norms, creation of new institutions, including local community organizations for performing a variety of roles in water supply & sanitation management, privatization, organizational strengthening, and building human resource capacities.

As regards actual reforms at the level of ULBs under JNNURM, Visakhapatnam has the distinction of having introduced all the reforms pertaining to water supply and sanitation. Other cities to have taken proactive steps in implementation of the reforms are Vijayawada, Chennai, Coimbatore, Greater Mumbai, Hyderabad and Madurai. The overall progress on implementing reforms has been slow (only seven mission cities carrying out active reforms) and more activity is seen in the sphere of implementation of the projects (Indian Infrastructure, 2009). There has been growing criticism about implementation of the proposed project-linked reform agenda, and many cities prioritizing projects over reforms.

While all the cities have committed to introducing the mandatory sector reforms in order to access central funds, these reforms have not been internalized widely. There is limited awareness on commitments made and their implications for changes (Cezayirli and Basu, 2008). Also, only e-Governance, municipal accounting and property tax have been kept as mandatory reforms areas for the ULBs whereas other important components such as administrative reforms (organization restructuring, changing reporting systems and procedures, human resource development and changing staffing patterns) and building PPP have been kept under optional category. There is no emphasis on metering, volumetric pricing of water and introduction of pollution tax & sewerage charges. Unless connections are metered, the problems of high UFW cannot be addressed. The issues of inequitable access and inefficient use of water and poor financial health of utilities cannot be addressed unless water prices are set right. Unless pollution from sewage and industrial effluent is controlled, the expected developmental outcome of improved water services cannot be realized. In nutshell, for JNNURM to be effective, proper balance between infrastructure development and reforms needs to be maintained.

### 10.4.2 Principles Underlying Institutional Reforms

A lot many experiments have been undertaken both in developed and developing on restructuring of water institutions. Experience over the last decade suggests an emerging global consensus on some key principles of institution reforms. The key principles of institutional reforms include:

- Appropriate Public Private Partnership (PPP) in the delivery of water-related services including that with small-scale providers

- Decentralization of responsibility to the lowest appropriate levels of government to respond to local conditions and needs

- The building of autonomous utilities with commercial orientation and financial viability for service delivery in urban areas (Tiwari, undated)

Today, most of the utilities obtain water from the natural systems and do not pay for the resource. Neither do they pay towards the environmental cost of polluting the freshwater bodies caused by disposal of municipal effluent. This is because they are not concerned with WRM functions. Like the urban water utility, many agencies (like the irrigation department, the groundwater department) compete for the same resource. Often the sustainability of the resource base itself comes under threat. Only some of the large cities purchase water as they have to obtain bulk water supplies from reservoirs built by irrigation agencies of the state, primarily meant for irrigation and hydropower. Even in situations where water is purchased from another agency, the utility does not pay for the services. Eventually, the government writes off such debts.

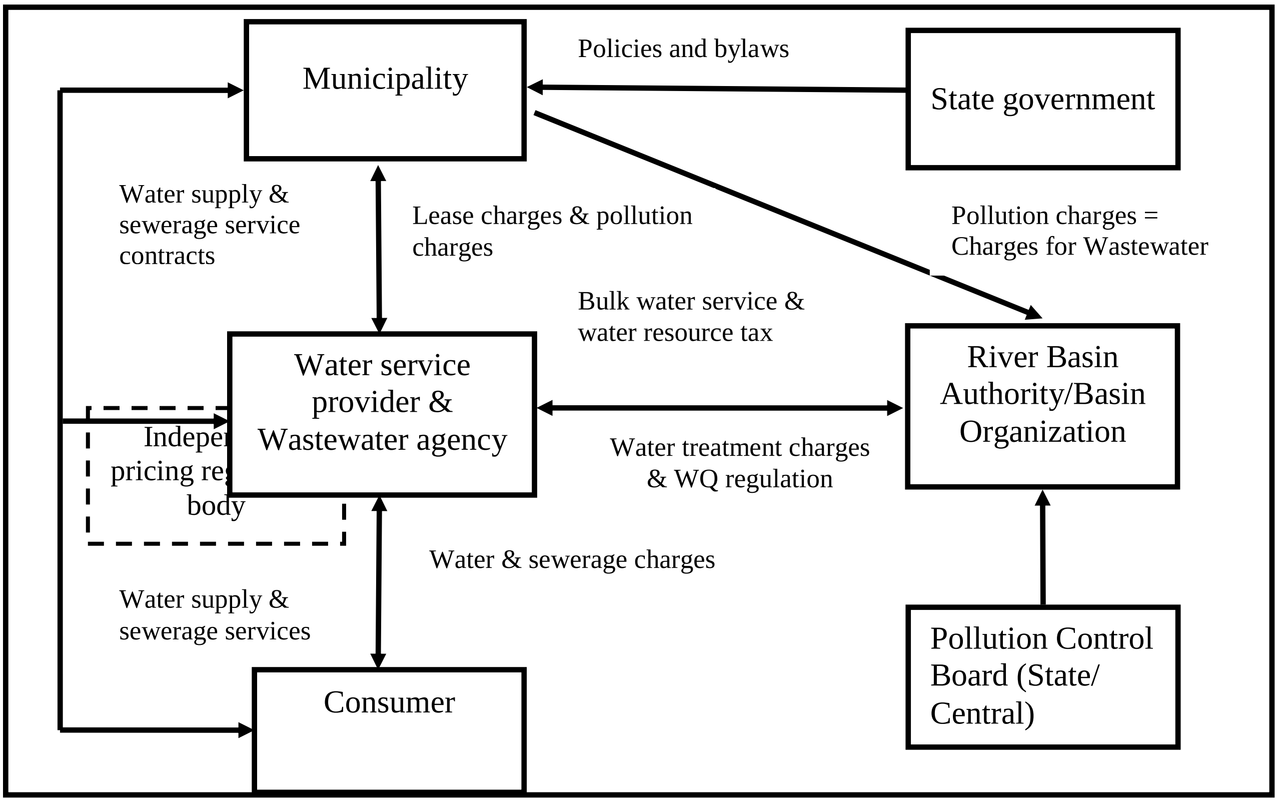
Separating out water resource management functions from water supply functions: The biggest intervention in institutional reform is the one by which the utility to confront the opportunity cost of using water, which includes polluting the rivers and groundwater through sewage disposal. For this, the urban water utilities have to be financially autonomous institutions, where they have to manage their affairs without interference and support from the government. Hence, corporatization of the utility becomes a pre-requisite. Also, the water resources management functions will have to be unbundled from water-related service functions, with separate line agencies looking after each one of them.

If the utility is autonomous and has to purchase water in bulk from the open market (which means the agency allocating water and the one using it are different), it will have strong motivation to recover the cost of supplying water by metering and pricing, and reduce the non-revenue water. Also, the utility would be under pressure to: reduce the dependence on purchased water by tapping the non-conventional sources such as desalination systems; and reduce the negative effects on environment caused by storm water disposal as these would increase its profitability.

On the other hand, as we have seen in the earlier section (Sibly and Tooth, 2007), the presence of formal water markets would force the basin authority, which is trading in bulk water, to manage the resources (aquifers and catchments) efficiently and sustainably. Here in this case, the utility will have to obtain water rights in volumetric terms from the river basin organization if it exists. It also will have to pay for every unit of pollution load it generates to the agency which is concerned with pollution control. The utility would recover the resource cost (depletion cost), and the cost of environmental degradation from the consumers. The utility will also have to recover the cost of building and managing the water supply &

sewerage infrastructure in addition to the above ones. The institutional design principle to be followed here is that the agency concerned with resource use and the agency which allocate the resource have to be different.

Figure 9: Improved Institutional Regime for Urban Water Management Sector




Creating an independent water pricing regulatory authority: The water pricing authority can decide the pricing norms and tariff level in consultation with the users. This is to be based on periodic review of the operating costs and efficiency figures provided by the utility. This essentially means that the utility will not be in a position to raise the water tariff on account of high operating costs. It will have to first raise the operating efficiency by reducing the non-revenue water, improving the staff efficiency and efficiency of the machinery and infrastructure. This will force the agency to be much more transparent in business.

Separating out water quality regulation functions from pollution control measures: The basin-wide regulation of water quality can lie with the River Basin Organization. Different models are available, wherein the Pollution Control Board can do water quality monitoring (Chéret, 1993).[27] The institutional design principle to be followed is that the agency doing regulatory functions of Water Quality Management and the agency which carries out pollution control measures should be separate (Frederiksen, 1998; Kumar, 2006).

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[27] In France, for instance, the RBO performs the regulatory functions, and delegates the task of setting up treatment plants to private agencies. The RBO carries out basin planning, collect fees for abstraction and pollution of the water resources, and also provide subsidies to local government for wastewater infrastructure (Chéret, 1993).

Stakeholder involvement in urban water governance: stakeholder participation should be encouraged in urban water governance, by creating a separate forum for their involvement to improve the overall governance. Such a forum can essentially: 1] provide periodic feedback on the norms for fixing the charges for water supply & sewerage connection, and provision of water subsidies to disadvantaged sections; 2] decide on the norms for water supply, supply schedules (24 x 7 or intermittent) and any restrictions needed in water supply during droughts; 4] decide on the criteria for provision of subsidies for adoption of water-efficient technologies by the urban consumers; and 5] decide on the penalty for illegal connections. Such a forum should be a legitimate institution, report to the municipal sub-committee on water & sanitation.

Figure 9 captures the overall institutional regime suggested for improved urban water management sector.

Here, the presence, characteristics and the actual role of a service provider would be determined by how big is the city/town in question, in terms of their technical, managerial and institutional capability. In a metropolitan city, the metro water board itself will be the water supply service provider. The role of private service providers will be limited to metering, bill collection, sewerage pumping etc. The service provider will have a much larger role in smaller municipalities, where the technical, managerial and institutional capacities for running the water supply and sewerage system and undertaking waste water treatment.

The charges levied by the service provider include the cost of production & supply of water, the sewerage collection cost, the resource cost and the environmental degradation cost. Part of this (the variable component of the production & supply cost or the total depending on who invests in building the water supply & sanitation infrastructure) will be retained by the service provider, while the resource cost (water resource tax) will be paid to the RBO. The resource degradation cost component of the water & sewerage charge would be paid to the Municipality, which in turn would pay this amount to the RBO for investments in WWT systems.

### 10.4.3 Institutional Reform for Water Resources Management

In this section, we would discuss some of the institutional regimes created in selected countries of the world for water resources management, including water quality management, wastewater reuse in agriculture and sustainable water allocation.

### European Examples in Water Quality Management

England and Wales have gone through four phases of institutional arrangements in urban water management. Before 1972, water pollution control infrastructure was under the responsibility of, and was owned by, local government departments, and was often combined with the water supply sub-sector. This led to serious inefficiencies because each municipality had its own small treatment plant and there was no critical mass of technical expertise and financial support. Regulation and water quality management rested with Inspectorates and the River Authorities.

Between 1972 and 1982 nine Water Authorities were created, and all the infrastructure with the exception of local sewerage were transferred to the new authorities in order to increase the scale of the organisations and to bring all water management functions into single entities. This led to the merger of many sub-sectors, including drainage and river management, and brought the regulatory and executive functions together, thus broadening their scope (for more detail see, Okun, 1977). The newly created organisations proved too large and unfocused, struggling with internal conflicts of interest, and unable to generate sufficient investment to meet increasing environmental quality standards.

Between 1982 and 1989, the Water Authorities were made more business orientated in order to increase their efficiency as well as their effectiveness. In addition, they were placed primarily under the supervision of the national environment ministry. Preparations were made for privatisation.

After 1989, the Government sold the water supply and wastewater infrastructure of the Water Authorities to public and private investors. These private enterprises remain operating in the same river basins. One of their main tasks is to generate finance for the overdue expansion and modernisation of the water and wastewater infrastructure in order to meet the strict EU environmental directives. As a result, tariffs have been raised. The regulatory and water quality management functions were taken over by the National Rivers Authority (NRA), which is also responsible for river management, and by the Inspectorates of the environment and of health. The enterprises are allowed to operate as monopolies within their region and, therefore, the new Office of Water was created as a financial regulator under the Ministry of Environment to ensure that water companies meet government policy, and that they do not exploit their monopolistic position at the expense of the citizens or the nations. It is a matter of continuing debate whether this arrangement is considered successful. In 1996 the water quality regulatory function of the NRA was merged with air and soil quality regulatory functions from the Inspectorates to create an American-style environmental protection agency.

In France, the local municipality has the autonomous powers to fix water charges, but delegates the responsibility of performing the water supply and wastewater collection & treatment functions to private agencies. The regulations of water quality management are performed by the River Basin Boards, which carry out planning, collect fees for abstraction and pollution of the water resources, and also provide subsidies to local government for wastewater infrastructure (Chéret, 1993).

## Norms for Wastewater Use in Agriculture

According to the 2006 WHO Committee of Experts, the QMRA risk assessment studies essentially validated the 1989 WHO guideline recommendation of 1,000 *E. coli*/100ml for unrestricted irrigation of most vegetable and salad crops eaten uncooked. These new WHO reuse guidelines provide developing countries with scientifically sound, more liberal, economically feasible and more flexible health guidelines which should help in promoting safe wastewater reuse practice for better nutrition and better health. It is estimated that globally, around 10 million ha of land is irrigated with treated or untreated wastewater, with the largest area under wastewater irrigation being in Mexico. Safe wastewater recycling and reuse can make a major contribution to water resource conservation in water short countries.

The US health guidelines for reuse of wastewater in agriculture were very stringent, though this was not based on any epidemiological evidence or health-risk analysis studies. In 1933 the State Department of Health in California established the first legal health guidelines for wastewater reuse in agriculture (Ongerth and Jopling, 1977). The standard set for unrestricted irrigation of vegetable crops normally eaten raw was 2.2 coliform bacteria/100ml of effluent. This is basically unachievable without very expensive high-tech treatment facilities.

. Many countries throughout the world copied those standards but few were able to enforce them. With such strict and basically unenforceable regulations, governments found it difficult to take effective action to reduce health risks. As a results farmers adjacent to hundreds of cities and towns in the water short developing countries utilized the raw wastewater stream flowing from the cities for irrigation of vegetable and salad crops often eaten uncooked resulting in serious health problems. Health and water authorities were unable to act in most cases due to the high cost of wastewater treatment required to meet their own unobtainable standards. This is a tragic case where *demanding the very best prevents achieving the good*. This is the first example of the global impact of wastewater reuse guidelines and regulations originating in a highly developed country which inadvertently had on the developing countries (Shuval, 2007)

Shuval et al. (1997) made the first attempt at developing a scientific QMRA - *quantitative microbial risk analysis* and cost-effectiveness approach based on a mathematical model (Haas *et al*., 1993) and experimental data, to arrive at a comparative risk analysis of the various recommended wastewater irrigation microbial health guidelines for unrestricted irrigation of vegetables normally eaten uncooked. The guidelines compared were those of the World Health Organization (WHO, 1989), and those recommended by the USEPA/USAID (1992) and Israel, which has guidelines more or less similar to those of the USEPA.

Study by Shuval (2008) indicated that the annual risk of succumbing to an infectious enteric disease from regularly eating vegetables irrigated with treated wastewater effluent meeting the World Health Organization Guidelines of 1000 *E. coli*/100ml (WHO, 1989) is negligible and of the order of $10^{-6}$ to $10^{-7}$ (One person per million or 10 million/year). The USEPA considers an annual risk of $10^{-4}$ (one person per 10,000/ year) to be acceptable for microbial contamination of drinking water (Regli *et al*., 1995). Thus according to the initial QMRA study of Shuval et al. (1997), the WHO Guidelines of 1989 for Wastewater Reuse in Agriculture were some 100 to 1000 times safer than what the USEPA itself recommends as the degree of safety required for drinking water.

According to the cost-effectiveness estimate provided by Shuval (2008), treating wastewater to meet the USEPA/ USAID guidelines would result in an additional cost, over and above the cost of treatment to the WHO guideline levels, of some $ 500,000 to $ 1,000,000 per case of disease prevented. This analysis applies, more or less, to the Israeli recommended standards (Ministry of Environment-Inbar Report) as well, which calls for 10 *E. coli*/100 ml and additional strict requirement for BOD, SS, turbidity and chlorine residual. Shuval et al. (1997) concluded that it is questionable if such a high level of wastewater treatment is justified for the irrigation of crops eaten uncooked, from a public policy, economic and/or public health point of view.

## South Africa's Legislative Framework for Ensuring Access to Water for Basic Needs

Since 1994, four key policy documents with respect to water and sanitation have been produced in South Africa. They are: Water Services Act (Act 108 of 1997), National Water Act (Act 36 of 1998), White Paper on Basic Household Sanitation (DWAF 2001), and Draft White Paper on Water Services (DWAF 2002a). The National Water Act and the Water Services Act are the two important water-related acts in South Africa. In addition, we have the Bill of Rights and the Constitution, which advocate the right of everyone to an environment that is not harmful to his or her health or well-being and to have that environment protected for the benefit of present and future generations (sustainability) (Hinsch and Westhuizen, 2003).

The National Water Act focuses on the management of the water resources in the natural environment. The main area of focus of the Water Services Act is on ensuring that water is provided to the population, with a particular emphasis on the previously disadvantaged and un-provided sector of the population. The emphasis of the two acts is different, with the National Water Act focusing on the water in the river, and the Water

Services Act focusing on the water as soon as it is extracted from the river or dam as a water supply (Hinsch and Westhuizen, 2003).

The main area of focus of the Water Services Act is on ensuring that water is provided to the population. The quality of potable water, taken or discharged into any water service or water resource system in terms of section 9(1) (b) of the Act, is described in clause 4 as follows:

*Quality of potable water: The quality of potable water provided to consumers must comply with SABS Code 241: Water for Domestic Supplies ; (2) A water service provider who is at any time, unable to provide potable water in compliance with SABS Code 241: Water for Domestic Supplies, to consumers, must inform the Minister and the Province and take reasonable steps to inform its consumers- (a) that it is unable to provide potable water of the prescribed quality; (b) of the reasons therefore; (c) any precautions to be taken by the consumers; and the time frame, if any, within which it may reasonably be expected that the prescribed quality will be provided (*National Water Services Act, 1997, South Africa*).*

The Act, however, does not explain the impact of water and sanitation on health, and the importance of health promotion and hygiene education. The role of DWAF is, therefore, changing from being a direct provider to being a sector leader, supporter and regulator. Its responsibilities include policy-making and strategy formulation, legislation, allocation of funds, grants and assistance, the setting of minimum standards, the preparation of guidelines, monitoring and evaluation, and the supply authority of last resort. Sanitation is not the responsibility of one government department. The Department of Health is responsible for public health and water quality monitoring.

The National Water Act provides for coordination between water resource management agencies and service agencies. Section 9 of the NWA requires catchment management strategies to take into account the development plans prepared as per the provisions of Water Services Act. All Metropolitan and District Municipalities, and any Local Municipalities authorized to fulfil the role of a water services authority, must prepare water services development plans in terms of the WSA. These plans form part of the Integrated Development Plans that municipalities must prepare in terms of the Municipal Systems Act, 2000 (No. 32 of 2000) (Hinsch and Westhuizen, 2003).

A water services development plan will be the principal source of information to a responsible authority for the determination of allocations to a municipality. The plan's requirements vis-à-vis water quantity and quality must be reflected in the catchment management strategy of water resources management agency. Some of the data in water services development plans will be incorporated into the national water resources information systems, and will therefore also contribute to national water resources planning. Conversely, when preparing its water services development plan, a water services authority must refer to the relevant catchment management strategy for information about the availability of water to support proposed water services targets, and requirements for the quality of waste water that is to be returned to the water resource after use (Hinsch and Westhuizen, 2003).

## 10.5 Organizational Strengthening for Urban Water Management

### 10.5.1 Evolving Community Participation in Urban Water Management

#### Introduction

Increasing community participation is a major step towards capacity building in urban water sector, and is part of the institutional reforms process. But, this can also result in organizational strengthening. The word participation can be defined as the "[a]ct of being involved in something" (Wates, 2000). "Community participation means some form of involvement of people, with similar needs and goals, in decisions affecting their lives. Charles Abrams defines community participation as, "the theory that the local community should be given an active role in programs and improvements directly affecting it". It is only rational to give control of affairs and decisions to people most affected by them. Besides, since no government or authority has the means to solve all the public problems adequately, it is necessary to involve people in matters that affect them (Abrams, 1971).

For community participatory projects, it is not a must to have an already well organized community right from the beginning but the sense of community can be achieved during the course of the project, which can also be one of the objectives of including community participation in development projects."

Participation can either represent assigning certain decisive roles to the users, where they share the decision-making responsibility with the professionals. The other type of participation is where there is no shift of responsibilities between the users and professionals but instead only the opinion of the user is considered while making decisions (Habraken, 1975).

After Sherry R. Arnstein (1969), there are eight rungs of participation: manipulation; therapy [Non-participation]; informing; consultation, placation [Tokenism]; and partnership, devolution of power, and citizen control [Citizen Power]. Manipulation and Therapy are cases of least participation. Informing, consultation and placation occupy the middle rungs of the ladder, and is termed as "tokenism" where the people are allowed to participate only to the extent of expressing their views but have no real say that matters. The last three rungs, partnership, delegated power and finally citizen control at the top of the ladder, are termed equivalent to "citizen power" and this is where true and meaningful participation takes place.

Sh*aring of information with communities,* as a starting point for community involvement and participation; information helps communities to understand issues and bring their commitment to the process of partnership.

*Consultations with communities* with a view to assess their effective demand (affordability and willingness to pay) for the services; such consultations helps service providers to understand community preferences and to move away from top-down planning to participatory planning approaches.

*Enabling communities* to participate in the decision-making process; this will call for necessary institutional and legislative reforms (e.g. to provide better access to communities to funding sources and security of tenure) and preparedness on the part of governments and service providers to involve communities in vital areas of technical and financial decision-making. In the final analysis, effective community participation not only ensures sustainability of investments and greater efficiency in the sector but also strengthens the foundations of public-private partnerships by bringing in greater transparency and public acceptability to the process.

Community participation might be possible even under PPP, provided an enabling legal and institutional framework exists.

## What Does Community Participation Mean in the Context of Urban Water Management?

The true community participation in any development programme starts when the community is given the full power to decide: how they like to be involved or in other words, what should be their level of involvement in the programme. This should be the guiding principle in any programme seeking community participation. This is far different from and far more justifiable than the official agency or an external agency deciding their role on their behalf, even if the latter means anticipating a very substantial role for the community. The community can then decide "what should be the level of their involvement" on the basis of the knowledge, skills and resources that it can mobilize. The underlying value in the entire argument is that the community is in a better position to articulate their expectations vis-à-vis participation in a development programme rather than the external agency.

Delegating the entire responsibilities starting from planning to execution and operation and maintenance, to the communities without having a realistic assessment of its needs and concerns will not result in their effective participation. The recent case of the central government's scheme of construction of civil structures for rural water conservation is a good example. The government wanted to implement the scheme every village, and funds were to be transferred to the local Panchayats. In one Panchayat, when the scheme was announced, the village Sarpanch expressed his opinion that the priority for his village was "flood control" and not "water scarcity". Also, investing in an expensive water supply system when the community is already having individually-managed local supply sources, which is often the case, can result in poor demand for water and poor financial and economic viability of the scheme itself.

The point here is if the community wants to be involved in the planning of a scheme or wants to have a say in the decision making with regard to starting a new scheme, it should be allowed to do so under the existing legal framework. Or if the community thinks that the planning of a scheme should be done by a more competent technical agency which operates at a higher level and with a larger jurisdiction, the legal framework should enable this.

But, the upper boundaries of involvement for a local community institution in urban water management activities (either in planning or in execution, or in repair & maintenance or vigilance etc.) would be defined by its operational jurisdiction, the level at which the scheme operates and the physical characteristics of the scheme.

As regards the first one, often local community institutions are created at the level of a ward or sub-unit of a ward, depending on the size of the population. But, the hydraulic systems boundaries of water supply, drainage or sewerage scheme may cut across the jurisdiction of several community institutions. The needs and priorities of one community would be different from that of other community. If community has to be involved in planning of the scheme, this would make planning process complicated. Therefore, for participation to be meaningful, it would be advisable that the next layer of community institutions is created at the level of the hydraulic infrastructure. This will help internalize some of the externalities in local management induced by conflicting management decisions taken by different local communities.

Let us now see how the physical characteristics of the scheme would define the level of involvement. For simple local schemes (for instance a well-based scheme with a pumping device, a storage tank and distribution network serving one ward or sub-unit of a ward), it would be easier for the "ward committee" to even plan and manage. The same will not be true for a scheme which involves long distance water transport through pipeline involving heavy pumping machinery, and leak detection equipments like the one found in Gujarat.

But, for a utility to start the process, first it has to understand how the community likes to be involved in urban water management. This would depend on what is desirable level of participation in a given situation and what is achievable. For a given community, the desirable level of participation is determined by its own perceptions of "participation", and the ability to participate. This is in addition to "physical system characteristics", which would influence the level of participation to a great extent.

Knowing both and taking a decision is a complex and ardous process. The reason is that the community's perceptions of and ability to participate would change according to their level of knowledge and exposure and capability to mobilize resources. The capability can be social (relationship among the members and or with agencies), economic and human resource-related.

Besides the desirable level of participation, degree of participation i.e., the extent to which community will participate in performing a particular function, also matters. Here comes the "willingness to participate". The willingness to participate would change according to the priorities of the communities. In a highly cosmopolitan community, the ability to participate in planning and management decision making relating to urban water systems and to mobilize resources for the same might be high. So what is desirable is higher level/order of participation in this case. But, the community may not have the time to commit for achieving the desirable level of participation. Conversely, the community may not perceive the opportunity cost of non-participation to be significant, as its ability to manage water from alternate source might be high. Hence, there would be a big gap between what is desirable and what is achievable.

Against this, in the case of slum dwellers, the knowledge, skills and resource mobilizing capability will be much less as compared to a cosmopolitan locality. But, the community might have more time to spare. Also, the opportunity cost of non-participation in this case would be high, as its ability to manage water supplies from alternative sources might be extremely poor. It might also be possible to come across. Hence, the most desirable level of participation might be low in the form of their involvement in repair and maintenance. But, it would be achievable.

The extensive literature and numerous research studies have identified many other factors that determine the degree of participation. Important ones include: a] homogeneity of the group/community (communities from the same clan, religion, caste, creed etc. are likely to participate more and better than a heterogeneous society); b] incentive (whether financial, natural or human asset gains, e.g. capacity building) which community see/perceive in case of participation; and c] effective leadership[28]. Here it is important to remember that the incentive structure can influence the opportunity costs of non-participation and therefore the willingness to participate.

In case of community participation in the management of Urban Water Supply system (UWSS), following phases can be identified:

a) Pre-planning phase: In this period the implementing/government agency conducts various studies related to the feasibility of WSS, management capacity of the community, natural resource etc and collects related facts and figures. Active participation of the community (for understanding their management capabilities and interest in WSS management) is an important factor of this planning phase. Apart from this, small scale IEC activity is also initiating to create environmental awareness. This is the first phase of rapport building and exchanging information regarding cost sharing and ownership.

b) Planning Phase: The community gets more attention in this phase. The agency conducts various cluster level meetings and understands people's knowledge about resource management. In this phase agency gains the faith of the community and the two involved stakeholders develops closer working relationship. Community starts to participate in decision making. The following steps are very important in this phase:

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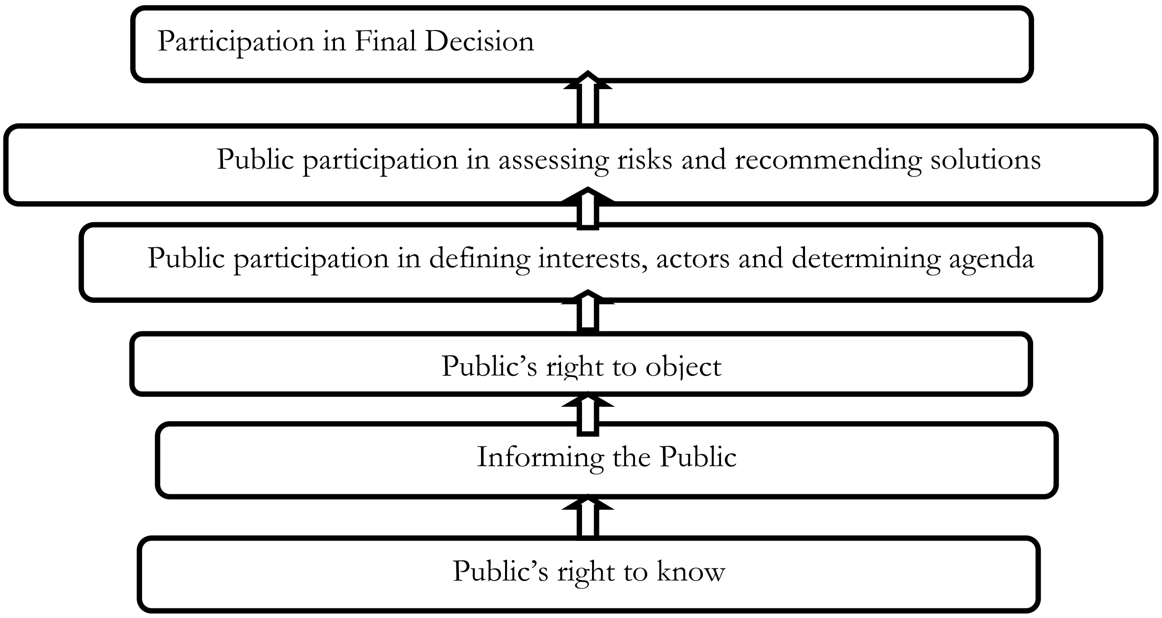
28 Probably the most important in recent times to get community participation, e.g. include *Ralegan Siddhi* and *Hiware Bazaar* watershed program both in Maharashtra, India.

c) Execution phase: By this phase community develops a sense of ownership in the supply system. They start procuring materials and services with the help of the agency. They also ensure the quality & quantity of materials, quality of work and proper usage of man, machines & material etc. By this phase, scheme gets completed and is ready for operation. At this point there is need for strong institutional set up backed by equally strong legal framework to run the system in proper shape.

d) Monitoring Phase: By this time, the system has started functioning. Various capacity building and training activities are also carried out depending on the role community is expected to perform. If the community is capable of running the system, at this stage, the agency takes up the role of technical advisor. In this phase, community will operate & maintain the system through the set institutional/legal framework and technical (in some cases also financial) support will be provided by the agency or government.

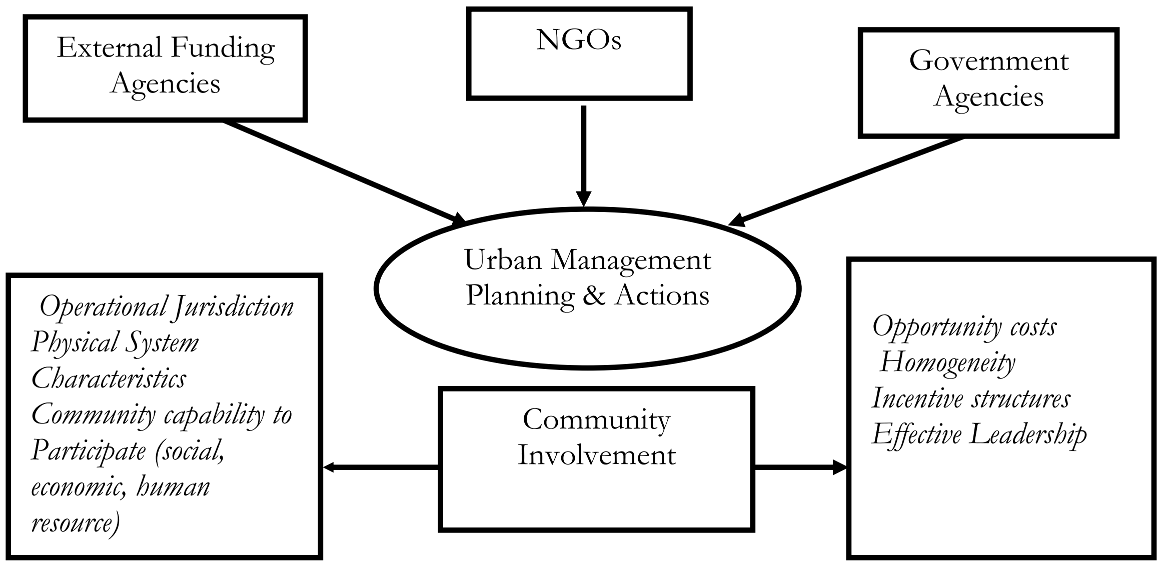
Figure 10: Steps of Community Participation
(Source: Weidmann and Femers, 1993)




It was however seen in most of the externally-aided or government-supported projects that once the project is completed and fund flow stops, involvement of people/community gradually dies off. Therefore, to sustain the participation or local institutions, important is to have proper exit point options before the project gets completed. Therefore, requirement of an Institutional framework backed up by strong legal support becomes all the more important.

In sum, it is understood that there is a need for an enabling legal framework which would allow the communities to decide on the level and degree of its involvement in any urban water management interventions. But, from an operational point of view, the two aspects need to be kept in mind while thinking about the appropriate institutional framework for participatory institutions and the potential roles they could play in urban water management. They are: what is the desirable level and degree of participation?; and what is achievable in a given situation? The desirable level of participation is governed by the physical system characteristics, the community's knowledge, exposure, resource-mobilizing skills. The willingness to participate would depend on the opportunity costs of non-participation. The degree of participation is determined by homogeneity of the group, incentive structures, social/economic/human capabilities and leadership (Refer Figure 11).

Figure 11: Community Participation in Urban Water Management




## The Benefits of Community Participation

The process involved in securing true community participation in development projects like the water and sanitation projects could be complex and ardous, demanding greater amount of time, resulting in higher investments, than what would have been required to implement a project in a conventional techno-centric approach (James, 1998).

Besides, there is a fear among governments of uncontrolled empowerment of people and lack of trust in their ability to make sensible decisions, which prevents the governments to change their paternalistic approach in decision-making. The only way that such issues against participation can be resolved is by looking at participation from a broader perspective and by weighing its benefits versus limitations. But, community participation could result in the project yielding greater social benefits and reducing the social costs. In addition to the positive externalities associated with community empowerment, community participation in planning could result in maximum benefits of WATSAN provision going to the poorest urban households and communities; reduced expenditure on guarding pipeline networks, reduced expenditure on detecting leaks, and leakage & theft prevention; reduced transaction cost of metering and pricing water volumetrically.

The realization that social benefits are far superior to physical benefits, and people's empowerment is necessary for enabling them to become productive citizen's has to be made on part of the implementing agencies that the empowerment of people is necessary for enabling people to become productive citizens. The authorities need to change their attitude towards people, on one hand while on the other hand; the people need to be guided for participation and making informed decisions. For instance, integrating the views and concerns of the local communities using a bottom to top approach could help fix alignments for effluent channels and locations for wastewater treatment plants so that they do not become nuisance to the community living in the neighbourhoods.

## Conditions for Improved Willingness to Pay for WATSAN Services

Habitat (1997) identified some of the key factors that influence the willingness of communities to pay for services, and hence relevant to utility managers and investment decision-makers:

**Security of Tenure**: A household which is unsure of its tenure will continue to pay to water vendors to meet its daily needs but the willingness to invest in a new and improved service depends directly on the security of tenure of the household.

**Level of Service:** One of the most important planning decisions concern the level of service. The new facility should provide a level of service better than the available options. For example, in one study in Kenya, it was observed that households which used vended water tended to be further away from other sources and had fewer women among them. Another situation, which is common in India, is that the households and societies drill their own bore wells, and become self-reliant, even though the quality of water obtained from underground sources is often not of good quality.

**Choice of Technology:** Community involvement is important in the selection of technology so that the design that has been adopted is what the community wants, and therefore is prepared to pay for and is able to maintain.

**Reliability:** Vended water is usually quite a reliable source and a higher level of reliability is needed to wean away customers from the vendors, if they are operational in the area. A piped system that is not reliable enough would not only fail to attract customers but would often result in large unpaid bills due to a distrust which is difficult to remove even when the reliability of service improves later.

**Price of Water:** Price is, no doubt, the most important determinant of a household's decision to opt for a new source of supply. On the supply side, water pricing has been based on such established methods as marginal cost pricing or cost recovery. Prices determined by such methods however fail to capture the ability or the willingness of a household to pay for the services and whether it would avail the new services. A mismatch between the two often results in high-quality piped water systems bypassing large low-income settlements towards higher income destinations.

## Role of Communities in Urban Water Management

Community participation in the context of urban water management is a complex theme, and has many dimensions. It can be at different degrees in different contexts. The involvement of community in urban water management could cut across various spheres viz.

1] Planning of water supply & sewerage systems (mainly having an influence in the selection of the type & nature of technical systems for water supply, sewerage disposal, wastewater treatment supply, water supply schedules)

2] Delivering certain services, which are parts of urban water management activities

3] Overall governance of urban water as civil society --including making of the rules for fixing the price of water, introduction of supply water restrictions, deciding on investment/funding priorities, provision of budget for public auditing

4] Theft (water) detection, illegal dumping of solid and liquid waste, identifying the families eligible for receiving the benefits of subsidized WATSAN provisions.

They are discussed below under separate headings.

**1] Community role in urban water management planning**

In areas where a formal water management system does not exist, the community has to be involved in the planning of urban water management projects. The involvement can range from: i] the community having a say in selecting the nature of the technical system for water supply, sewerage disposal and practices for wastewater treatment (whether centralized or decentralized) and supply schedules; ii] use of community's knowledge in selecting the type of water supply and sanitation system, flood control and storm water management practices; and, iii] taking into account community's own needs and priorities with respect to the quantity and quality of water to be provided, and affordability of services, drainage and flood control; and iv] identifying solutions for water supply management and wastewater treatment that can come from behaviour changes[29].

The community may not like to depend on a single system when it comes to water supply and instead may like to have multiple systems, which would help improve the reliability of water supply and increase the resilience to shocks caused by disruptions in water supply.

- The community can identify the most appropriate technical system for water supply and sewerage disposal based on various considerations. Some of them are: affordability, efficiency, sustainability and equity; and easiness in operation & maintenance. The efficiency will also include their "easiness in accessing and using water from the public system" and using "sewerage disposal systems". If the families within a certain community are already having septic tanks for sewerage disposal, their preference naturally won't be for a centralized sewerage system. Instead, they would be happy with a decentralized wastewater treatment system like the reed bed. Sustainability consideration would include the reliability, adequacy, and the "quality"

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29 The UK's sanitary waste treatment project is an illustrative example. Despite the behavioural research findings clearly demonstrating the significant potential for specifically designed behavioural change campaigns to reduce the solid loads entering the wastewater systems, an alternative marketing program was eventually implemented. Due to the perceived 'risk' of a behavioural solution, a technological investigation was undertaken. Despite the fact that the removal of storm water from the wastewater systems was identified as the most effective solution, and screens were the least sustainable option, the regulative system privileged the "screen" option. This case also shows that there is a strong expectation and belief that there is a technical solution that is going to solve water management issues in a more sustainable way, rather than needing to tackle the issues requiring political leadership and social changes. The analysis also revealed how this belief led to exaggerated claims of the need for a 'screen' so that the difficult job of finding political solutions is not faced.

that meet the water quality requirements. The culture would have a significant influence on deciding the quality and quantity of water.

- In case, the technical options chosen on the basis of these four considerations are such that community involvement in O & M is possible, "easiness in operation & maintenance" would be an important consideration in selecting the alternative (with the help of technicians or trained person from the community). If RWHS and RO turn out to be two viable water supply options for a locality, then from community management point of view, RWHS would be the ideal option as it would not require skilled manpower, which may have to come from outside the community, to run it.

- The community can also participate in the decision-making with regard to the most appropriate system for solid waste collection, including the mode of collection, frequency of collection, mode of transport and the viable sites for disposal of the solid waste, and their role in the entire operation.

- The community can be and need to be involved in the assessment of the water demand, through self-surveys. It has been demonstrated that one reason for the low level of willingness to pay for WATSAN services is the estimates of water demands which the communities don't accept. This results in expensive systems passing through poor urban neighbourhoods to serve rich localities. The resulting community consensus could lead to firm commitments to contribute financially to improved services.

In all the situations cited above, the role of the community is decisive, in which certain decision-making responsibilities are shared with the municipal water professionals.

**2] Community as Service Provider**

The concept of partnership is closely related to systems thinking and is a form of structured social network. The cultural context has lots to decide the types of partnership that are emerging in the management of urban water in different countries. They may take one or more of the following patterns: i] consultative; ii] collaborative; iii] contractual; iv] client oriented; and, v] supervisory/regulatory.

Apart from the formal service providers, there is a wide range of water providers in the informal sector ranging from households sharing a private house connection to completely autonomous community-based systems. Van Wijk (1997) had summarized various forms of partnerships for water services as:

- **Group taps** are closest to private connections. Under this system, households jointly take one private connection and share the bill. Essential social conditions for the success of this system are that the users form their own group and decide in whose name the connection is registered, where the tap is located and how costs are shared.

- **A communal water point** consists of several taps with a bucket stand, a drain, a soak-pit and a valve box which contains also the water meter and can be locked. The user group chooses a small (usually three persons) tap committee, which unlocks and locks the valve box, oversees proper water use, receives and divides the water bill between the user households, collects the money and pays the public authority.

- In **community-managed vending kiosks**, water is sold per bucket at public vending points or kiosks. Sometimes the vending is done by the utility, or the utility gives the vending rights to concession holders in the private sector. However, in a growing number of cities vending is not done by commercially operating concession holders, but by community groups. The committee manages the overall fund and takes care of maintenance and repairs of the water supply, up to replacement of pumping equipment.

- An **autonomous local distribution net** is operated by a community organization which buys water in bulk from the urban utility. The utility either installs a metered master connection to the city net, or fills a community reservoir. From there the local community distributes the water on to the members of the local water user association through private connections or shared taps. The community pays the water charges to the utility and operates, maintains and manages the local system.

- Small **autonomous water supply systems** are found to be operated by a community. User households are members of a local water users association with an elected water management committee. The water utility gives technical advice and helps arrange for the investment loans, which are partly paid by the community through the water tariff. Sometimes water utilities establish a special unit for experiments with alternative water supply systems. This can also be modelled under the public-private partnership with the public water supply agency owing the assets, and a private agency (here a formal group of the community) managing it. The private agency can arrange loans for capital expenditure. Along with this, the community can get together and run a decentralized wastewater collection and treatment system for a locality, which is ideal for the topography, geo-hydrology and climate of the locality depending on the land availability and prices, instead of leaving the wastewater to a centralized treatment system.

- **Large surface water based water supply schemes (LSBWSS):** This kind of community owned, operated and managed schemes can be seen in Kerala with more than 4000 HH connections and with commercial or industrial connections. All connections are metered. They are forming a Beneficiary Group (BG) with two members from each member house and registering with district registrar. After this with the help of Government and other development agencies they are implementing a scheme with partial cost sharing. The BG is working with the help of a supporting organisation (SO), which is normally an NGO. After the commissioning of the scheme Government the SO stop the assistance and the O& M cost is fully borne by the BG. They are setting up offices and appointing field level and administrative staff for running the scheme. This includes pump operators, meter readers & bill collectors, plumbers, accountants etc. The offices are provided with computer billing facility and other necessary equipments by the government. Also under the control of local government they constitute an apex body with the representation of BG, water authority, and the Electricity Board and other related officials and people's representatives. This body gives expert suggestions on issues related to new connections, water tariff and technical matters. Here an important feature is the BG is supplying water to public institutions like schools, *Anganwadis* etc., free of charge[30].

In this kind of WSSs tariff reduction is very prevalent by virtue of cost saving resulting from timely maintenance. Sometimes the BG is taking decision to reduce water charge, owing to fund surplus.

The conditions under which and the skill levels with which the community can manage water supply changes as one move from model 1 to model 6. Group taps might work for slums/housing stocks, where individual families don't have the financial resources to apply for an independent connection, and where the utility has the network which can supply water. Trust is an important factor driving the success here.

Communal water points might work under situations of large slums, where people live together for several years, and there is some amount of community bonding and the social viability of creating a user group is high.

The third one is ideal in situations where it is infeasible to have individual connections from an economic point of view due to scattered or floating population.

The fourth one would work when the water supply agency is mandated to handle only bulk water transfer. One example is WASMO's drinking water supply model in Gujarat. The pre-requisite here is bulk metering of water supplied at the distribution point.

The fifth one would be ideal when the urban community is well established, and has high level of confidence in its organizational, managerial and financial capabilities to set up a water supply system and run it; and integrating it one the centralized water supply run by the utility won't make economic sense. Here again, the technical inputs for design and construction of the water supply systems should be made available from the utility.

The sixth system is feasible where an existing system has failed to meet the water demands of community. If the local self government and community are willing to come up with committed participatory planning and action, this strategy will definitely work for new schemes also. The capital cost, maintenance cost and water consumption& misuse will be very less and the institution establish with some other development activities in their area of operation.

De-centralized, "informal" private providers: community-based investors, managers and operators work with NGOs and public utilities to improve access to drinking water in neglected neighbourhoods left off the municipal grid. Informal participants can refer to unregistered individuals, families, community groups, NGOs and small enterprises (Habitat, 1997).

In addition to the above mentioned forms of partnership, there can be other forms of community participation in UWM. Such forms of partnership are applicable to urban areas where large apartment complexes are very common, and individual houses are a few,

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30 A WS Scheme at Chavara –Panmana in Kerala has been constructed under Tsunami rehabilitation, is having some specialities in community participation. The project was implemented for 2 Gram Panchayaths with coverage of more than 21000 families. The *Jalanidhi* (KRWSA) was the implementation agency with the support of an NGO. Social mobilisation including capital cost-sharing collection has been done by these agencies with the help of local self governments. Each beneficiary HH had paid Rs. 1200/- as their capital contribution. Total project cost was 28 crore. Estimates preparation and related works has been done by KRWSA and the construction activity has been awarded to Kerala Water Authority. After commissioning the scheme has been transferred to BG and full O&M cost will be borne by them only. An office with trained persons had set up for operating the scheme by the BG and it will work with the revenue income from the water supply. Here different agencies and community participated for implementing a WSS.

and where the utility's services are limited the following: bulk metering of water supplies at the level of the housing society or apartment block; and collection of solid waste only from only one pick up point in each society. Going by Sherry Arnstein (1969)'s definition, this can fall under the higher degree of participation called "citizen power".

- The housing society can obtain water from the "single line connection" provided by the utility to each one of the apartment blocks, and store it in storage tanks (underground and overhead) and supply to individual households using pumping devices.

- The housing society can decide to measure volumetric water uses of individual households by installing water meters for every house-connection and charge for water accordingly. This will encourage efficient use and ensure proportional distribution of the costs of obtaining water services; and equity in sharing of benefits of water supply. The charges for meter installation and meter reading can be borne by the society which in turn will be recovered from the members.

- During severe water shortages, the housing society can also enforce regulations on water use to manage the demand for water by: supplying water from a centralized storage system for very limited time; and banning the use of large storage tanks inside the apartment.

- The housing society can also make arrangements for pick up of solid waste (garbage and other wastes) from each household and drop it at a common pick up point for the municipal scavenging unit). The charges for these services here are paid by the society members.

- The housing society can also invest in water treatment plants; treat the raw water supplied by the utility, and supply water to each and every household.

**3] Community in Urban Water Governance**

The community role in urban water governance could include the following:

- Participating in planning of urban water management system (as discussed above)

- Participating in the process of decision-making on the rules and norms for fixing water rates, water & sewerage connection charges, mode of pricing water

- Participating in the key decision-making including that on water supply schedules, and water supply restrictions, subsidies to be provided for the poor in provision of WATSAN services, subsidies for water efficient technologies, mode of collection of water charges

- Participating in the decision-making on the key investments/finances including the level of investments, the sources of finance, and acceptable terms and conditions of receiving finance.

- Its representatives participating in the public auditing of water utilities' works and annual income and expenses

- Setting the standards for monitoring [a group of representatives from water users] quality of construction, quality and quantity of materials, quality of work, and time frame for completion of works.

For participation of the community in urban water management to bring about positive outcomes, it is necessary that their level of awareness about water management and sound principles of water management are adequate.

### 4] Community Participation in Implementing Best Practices

- Assisting in "illegal tapping detection" raids conducted by the utility authorities

- Assisting the utility engineers in locating the water and sewerage lines that are old

- Assisting the utility managers in identifying the localities and housing stocks that are lacking in formal water supply systems and sewerage connections, and therefore the most vulnerable from the point of view of WATSAN services

- Taking water meter readings from housing societies and individual houses on behalf of the community organizations, and checking the functioning of meters

- Identifying the most eligible BPL households within the locality for receiving the benefits of subsidies for WATSAN services

- Collecting the water charges from housing societies and individuals and instalment payments of the loans received for obtaining water & sewerage connections and installation of sanitation systems

- Protection of the created assets from encroachers and criminals

- Helping the authority to control leakage through timely information and communication

- Setting up water meter repairing & plumping unit with minimum charges; arranging skilled teams for sewerage repair in the nearby areas

- Creating awareness among the local community about water conservation, avoiding misuse, health & hygiene practices related to water and sanitation

## Case Studies on Community Participation in Urban Water/ Environment Management

### 1] Senegal Experience with Community Participation in Urban Environment management

THE ENDA-Third World experiment in Rufisque, Senegal demonstrates that: that the construction of appropriate and low-cost infrastructures and facilities provides jobs and income for numerous young city dwellers; the value added - purified water and compost to cite but two examples - contributes to the struggle against poverty; community involvement in the project resulted in increasing numbers of local people developing a civic sense; women played a prominent role in improving the local environment; and above all, the methods used are particularly suited to low-income areas.

The Rufisque experiment shows that it is possible to use existing local community organizations based on traditional leadership for mobilizing action for improving local environmental conditions, even when the community has low literacy rates. It also shows that there is a need for intervention from an external agency, with funding etc.

The following groups were involved: the Inspection and Assessment Committee, a democratic district body: this committee is made up of district representatives, mainly old men, patriarchs whose status is more traditional than political. In the few instances where a local representative's membership of a political party has influenced his/her behaviour, this has had a negative effect on people's sense of involvement; and 2] the Rufisque local authority and the Rufisque administrator who were involved in granting land for the purification plant and in providing economic incentives for refuse collection.

Drawing on the experience acquired during an erosion control project, they decided to use the most basic local community entity - the district and groups of districts - as a foundation for the scheme. Traditional and modern meetings, theatre and other events were used to discuss the plans and news of meetings was passed on through the existing community networks. In this way, a structure was created which drew representatives from a range of community associations (men's, women's and youth groups) and which was responsible for planning, monitoring and evaluating the PADE scheme. This structure is known as the Local Management Committee. It subsequently included representatives from various sections of the government at department level (such as health) and from the local authority head of the Office of Services.

The local community could participate actively in the scheme at the following levels: 1] women, local representatives, elders and young people are on the Inspection and Assessment Committee and the Joint Committee; 2] community meetings and mosque gatherings provide forums for discussion; 3] district representatives participate in surveys and research to select beneficiaries of private sanitation and also in discussions and awareness campaigns, and in the management of materials and supplies; and, 4] district representatives and elders help to collect loan repayments.

The project had socio-cultural; socio-economic; political; health and environmental impacts. The way people used to look at solid waste disposal, and wastewater disposal has changed. Elderly people started denouncing traditional ways of waste disposal. May people have got employment in waste collection & disposal jobs and wastewater treatment systems. The urban local body has started providing funds for purchase of carts. The environment of the sea beach had improved due to safe sanitation works.

The scheme of refuse collection and sewage disposal and treatment is self-financing. The beneficiary households contribute a certain percentage of the cost of building the private sanitation infrastructure (30-70 per cent). This amount goes into a pool of revolving fund managed by the "local management committee" which gives guarantee to the contributors of providing the facilities. The same fund is used for self-financing of the sanitation systems in the low income districts.

### 2] Winterveldt Community Sanitation Project in South Africa

The Winterveldt Community Sanitation Project, launched in 2001, sought to build on an earlier project for provision of clean drinking water. The new project was designed to tackle both lack of awareness regarding appropriate sanitation practices and lack of access to adequate sanitation facilities.

Winterveldt community consists of approximately 25,000 tenant households in peri-urban settlements north of the City of Tshwane, South Africa's administrative capital, in Gauteng Province. Rand Water, an independent public authority, is Tshwane's main water supplier, supplying about 70% by volume. The remainder is supplied by the city's own sources. Low revenue collection rates from informal and low-cost housing areas coupled with the specific challenges of provision of water services to peri-urban settlements rendered development of new services difficult.

The Winterveldt Community Sanitation Project was initiated as a direct result of community pressure for improved sanitation services. It began with a pilot initiative, lessons learnt from which were applied to planning for other under-serviced areas in Winterveldt.

This socially inclusive approach to water services for peri-urban areas entailed a new way of stakeholders working together. The starting point was the establishment of a partnership model on which to base the awareness raising and facilitate construction activities. The partnership structure included the local community, Rand Water, an independent water authority; the Department of Water Affairs and Forestry and an NGO with its input mainly confined to overall evaluation.

Initially the community water and sanitation committee felt that tenants would be reluctant to contribute to construction of improved facilities owing to lack of land tenure, and that plot owners might take the opportunity to add to the value of their land by using subsidies to build communal toilets for tenants. This was addressed by approaching individual plot owners to explain the importance of ownership, and by targeting the subsidies at households. It was thus agreed that the householders, and not the landowners, own and would be responsible for maintenance of their facilities.

The working principles guiding the multi-stakeholder partnership were:

- The need for strong relationships at community level, supported by appropriate incentive structures, with the community acknowledged as client;

- The required social intermediation to be undertaken by both Rand Water and community organizations to provide support to community members with training and advice

- The demand-driven approach increases sustainability

- The necessity to delegate genuine control of the project to the community, whilst maintaining central support and monitoring

- The importance of an appropriate community-level financial framework, in which ceilings for per capita grant finance allocations and upfront contributions from the community are integrated to achieve incentives and to enhance sustainability.

By 2003, a total of 1,050 ventilated dry-pit latrines, the most appropriate and cost effective means of providing sanitation in this peri-urban setting, had been constructed, largely through the efforts of small, medium and micro-enterprises (SMMEs) established with mentoring from the project. Financing of the dry VP latrines was made possible through the community-based lending scheme established through the introduction of a social investment fund designed to provide financial support, training, information and technical assistance to organized community water and sanitation committees. Lastly, both women and men had the opportunity to become trained latrine masons - with more than 50% of the builders being women.

### 3] Learning from Case Studies

Experience from Senegal (Rufisque), India (Ahmedabad), Tanzania (Daar *e* Salam) and South Africa (Tshwane) shows that partnership between local communities and official agencies for improvement urban environment emerges under certain sets of conditions: when the urban environmental sanitation conditions are extremely poor; there is assurance of technical, legal and financial support from the external agencies including the local government; and there are proper financing frameworks at the community level are evolved for their contribution to be possible for building the essential private infrastructure. The local institution for urban environmental management can be built on the existing social, cultural and economic institutions in the locality, if they do not have political patronage. This can help overcome the problems of "social exclusion", and create inclusive institutions.

## 10.5.2 Water Privatization

### Factors Driving Privatization of Water Services

The loans from international development institutions, which are all public sector, government institutions, are central to the financing of nearly all the privatisations. Private investment from the multinationals themselves may be only a small part of the money involved.

In many cases, the main driving forces behind privatisation are the conditionalities imposed by the various international financial institutions (IFIs). These include the IMF, whose structural adjustment policies often demand the privatisation of state services, including water; the World Bank, which may make privatisation a condition of its loans to governments, or may supply finance via the International Finance Corporation (IFC), the arm of the WB which invests only in the private sector; and the Inter-Americas Development Bank (IADB), whose loans may also insist on privatisation. In all cases, the imposition of privatisation is effectively a political demand: there are well-established banking criteria for evaluating a company's credit-worthiness, which apply whether it is public or private (see 'Water in Public Hands'). The use of conditionality is also contrary to the explicit statement agreed by the Bonn conference on water in December 2001 that privatisation should not be applied as a condition of finance by any donors.

In addition, the loans of the European Investment Bank (EIB), an EU parastatal set up to finance developments of interest to European countries and companies, is often acting as a source of funds in Latin America available only to European private companies.
In addition, the political risk insurance arm of the World Bank, the Multilateral Insurance Guarantee Agency (MIGA) is providing financial security from risk for the privatised water concession of IWL in Ecuador, by providing protection against political, currency and even, to some extent, performance risk. The WB also incorporates the international arbitration court – ICSID – which is responsible for hearing claims by multinationals after termination of concessions.

### Public Health Impacts of Water Privatization

The literature review raised persistent concerns regarding access to water by the poor under privatization. The review also suggested that the public sector could deliver public health outcomes comparable to those of the private sector, as measured by access rates and decreasing child mortality rates. In terms of social equity and justice, privatization marked a troubling shift away from the conception of water as a "social good" and toward the conception of water--and water management services—as commodities. The results indicated there is no compelling case for privatizing existing public water utilities based on public health grounds. From the perspective of equity and justice, water privatization may encourage a minimalist conception of social responsibility for public health that may hinder the development of public health capacities in the long run.

A large amount of literature exist which criticize privatization of services including water on the ground that with increasing price of water, the poor are adversely affected. Most of the research on privatization looked at the financial aspect of the utility which got privatized including profitability, and therefore favours the idea. The recent research shows the direct social impacts of privatization, apart from the positive welfare effects estimated by some research studies. In the case of Argentina, it was found that after privatization of the services the child mortality rate had dropped by around 7.5% (Galiani *et al.*, 2002).

In the 1990s Argentina embarked on one of the largest privatization campaigns in the world as part of a structural reform plan. The program included the privatization of local water companies covering approximately 30 per cent of the country's municipalities. Using the variation in ownership of water provision across time and space generated by the privatization process, Galiani *et al.* (2002) found that child mortality fell by 5 to 7 per cent in areas that privatized their water services overall; and that the effect was largest in the poorest areas. In fact, we estimate that child mortality fell by 24 per cent in the poorest municipalities. These results suggest that the privatization of water services prevented approximately 375 deaths of young children per year. They checked the robustness of these estimates using cause specific mortality. While privatization is associated with significant reductions in deaths from infectious and parasitic diseases, it was uncorrelated with deaths from causes unrelated to water conditions.

Experience of sub-Saharan Africa from Dakar in Senegal and the cities of Nyeri and Eldoret in Kenya (source: RTI International, 2005) shows that privatization or private sector participation can happen even in poor and stagnating economies if there is sufficient political will. It also shows that privatization can also pay dividends in the forms of sustainability, cost recovery, efficiency, and equity. The efficiency improvement was in terms of larger number of connections; greater volume of water supplied; greater extent of sewage collection; improved access for the poor; greater cost recovery; and better environmental conservation measures. In all the three water utilities, incremental block rates were introduced.

It also shows that clearly-defined operating rules and contractual terms set by the government agency for the private sector would facilitate this. Also, the experiences show that the goals of efficiency and equity can be built in designing the operating rules of the private service providing agency.

## Issues in Privatization in Urban Water Services

- The three important elements of privatization are: Corporatisation of the agency including financial and management discipline; unbundling of various services into cost centres and "profit centres" and improving the functioning of each; and introducing full cost tariff.

- There is a need for making clear distinction between full cost of infrastructure & operation and the cost that includes the opportunity cost of using the resource.

- The biggest challenge in privatization of urban water supply is in making sure that the private agency does not use its natural monopoly over the water supply network to extend it to establish control over the resource itself, including the alternative sources which communities can access. This can partly be addressed by making sure that the resource is not privatized and the ownership of the same is held by a legitimate authority in "public trust". A RBO can also be one such authority which can allocate the resource to different agencies, including that for water supply.

- Chennai's metro water board had undergone major transformation since the late 70s and early 80s, which is in the path of privatization of the services.

- In situations where the resource is in plenty, the chances of making privatization of water supply a viable business proposition seems to be quite difficult. The reason is the ability of communities to access water from various sources

Table 33: Experiences with privatization Models in three African Countries

| Name of the City | Model for Private participation | Institutional Arrangements | Mechanism for Ensuring Stakeholder Participation |
|---|---|---|---|
| Dakar in Senegal | A supervisory public utility, monitoring "water performance contracts" of utilities (SONEE), was converted into a publicly asset holding company with the help of the World Bank. The existing assets of the water utility were put under the company | A public asset holding company entered into a contract with a private sector company for managing the system. Contract with the private company covered issues of efficiency (technical & financial); and equity. Company collects the tariff; keeps the fee as per the affermage contract | A ten year lease agreement was made by the private agency with the public asset holding company |
| NYEWASCO in Nyari, Kenya | Separate company formed for water services from the Municipal Council's water & sewerage department with the support of GTZ, Germany | The Company acts as an agent of the Municipal Council | Greater autonomy and reduced political interference |
| Eldoret Water & Sanitation Company, Kenya | First, the finance of the water & sanitation wing of the Municipality was "ring-fenced". The company was later on incorporated. | | ELDOWAS Board includes representatives of all consumer members—industries, urban water users, particularly the poor, corporate users. |

Source: RTI International (2005)

## Public-private Participation

Public private partnership in urban water sector is one form of privatization and the extent of privatization is determined by the mode of partnership. Therefore, it can be treated as part of the institutional reform process in urban water sector.

1. *Service contracts* are generally for one to two years. These are fee-based and are typically for specific components of the service, such as meter reading and billing and operations.

2. *Operations and Maintenance (O&M) contracts* usually are for five to seven years. Payments are fixed fee plus incentives linked to reduction in losses. One way to create incentive is to allow the private agency to retain part of the increased revenue owing to reduced losses. The city retains responsibility for capital investment required for repair and replacement works.

3. *Lease agreements* are generally for eight to 15 years. Under this arrangement the private party makes required routine investments for operations and maintenance. However, the responsibility for financing and planning major investments lies with the government. Risk is shared.

4. In *concession agreements* the private party finances and owns the facilities for a period of 20 to 30 years (time to depreciate investments and provide a reasonable return to the equity investors). Since payments are linked to direct collection of water charges, the private party benefits from reduction in UFW due to operation efficiencies and system rehabilitation.

5. Build-Operate-transfer agreements, the asset ownership is with the private party. Commercial risk is taken by the private agency. But, oversight of performance and water charges is done by the public agency, like in all other previous arrangements.

6. Joint ventures: assets are jointly owned by both the parties. Asset ownership, design & building, capital investment, O & M and commercial risk are shared. The performance oversight is done by the public agency.

In case of 1 and 2, the risk is covered by the government. In the case of 4 and 5, the private agency takes the risk.

Edouard Perard (2006) constructed a world map showing the percentage population in different countries served by private water suppliers. It shows that countries of South Asia are fully covered by public water supply; and in countries like the United States and Australia, the degree of private sector involvement in water supply is less than 40 per cent in term of the percentage of their population served (in the range of 10 & 40 per cent).

The IWE Cranfield PPP Database, Franceys 2003, which has international comparisons, show that the private sector participation in urban water supply is a function of the income level of the country. High income countries had higher degree of private participation. It also showed the private sector participation has been on the rise over a 12-year period from 1991 to 2002, with highest growth recorded in the case of upper middle income countries. Today, the upper middle income countries have highest degree of private sector participation in urban water supply (Perard, 2006). As the Map shows, many Latin American countries have over 70% of the population covered by private agencies; some having 40-70% and some 10-40 per cent. According to Braadbaart *et al.* (1998) the fact that secondary cities are too large for the kind of user management found in small towns and rural areas, and that they are too small and too numerous to be privatized is compelling reason for PPP in large cities.

## Success in Privatization of Urban Water Supply & Sanitation

Experience seems to suggest that private sector participation in urban water supply is likely to come up if country is politically stable and governments are powerful, and economic condition does not have great bearing on this (Perald, 2006). But, giving long-term concessions to the private sector companies have produced very mixed results. There is no question that the private sector companies have improved the management efficiencies of water utilities in many urban centres very significantly. Equally, the experiences have been dramatically opposite in many other cities, where several major performance indicators of the utilities managed by the private sector companies have actually declined compared to even the earlier dismal efficiencies of the public sector. This proves once again the validity of a simple development theory: there are simply no universal solutions.

Extensive evaluations carried out by the Third World Centre for Water Management in Asian, African and the Latin American countries, shows that even within a single country, the experiences have sometimes been very different. In Morocco, private sector concession of Casablanca can be considered to be a success, but Rabat by all accounts was a failure. The situation can sometimes be different even within an individual urban centre. For example, one of the two water concessions for Manila is working significantly better than the other. Nor is the performance of one multinational company similar all over the world. The same multinational company that has performed extraordinarily well in one City may have failed miserably in another city. There is thus no one universal positive or negative experience which justifies the paradigm of the privatization in terms of institutional performance (Biswas and Tortajada, 2003).

The independent evaluations that were carried out by the Third World Centre for Water Management in Asia, Africa and Latin America makes it evident that the paradigm that the private sector institutions will solve all the problems of water and wastewater management, efficiently, equitably and over a prolonged time period of 25-50 years of rapidly evolving national and global conditions, wherever they have had opportunities, is simply a non-tenable proposition. Private sector still has an important role to play, and their roles are likely to be much more significant in the future compared to what they are at present, but they are not going to be the panacea which many development institutions had proclaimed in the past, or are even arguing at present. We need to revise our views based on dogmas pro or anti public or private sector institutions, based on real facts and experiences (Biswas and Tortajada, 2003).

According to Biswas and Tortajada (2003), even under the most optimistic but realistic assumptions, it is highly unlikely that the private sector concessions will provide water and wastewater management facilities to more than 15 percent of the world's population, even by the year 2015.

It is thus necessary to develop a new institutional paradigm for water supply and wastewater management for urban areas of the developing world, since the widely accepted present paradigm for the future is unlikely to be the main approach of the future. Based on

**Box 2: Sri Lanka's National Water Policy to improve the performance of the National Water Supply and Drainage Board**

Water tariffs in the urban areas should be set at such a level that it should be possible to recover operating costs and depreciation, and should be gradually increased "to recover the full supply cost of providing services, including debt service and a reasonable rate of return".

Cross subsidies between commercial/industrial consumers and domestic consumers should be reduced to a reasonable level.

However, what constitutes a "reasonable level", or how it can be estimated, is not specified in the policy. It should be further noted that at present there are cross-subsidies also between projects, which also need to be progressively reduced, and perhaps eliminated for most cases, unless there are very special and specific justifications for maintaining them on an individual basis.

Sewerage tariff that covers operation and maintenance costs shall be introduced based on water consumption for the sewered areas, and also as and when sewerage services are introduced to these new areas.

For low-income people, appropriate life-line tariff should be available to ensure the affordability of water of sufficient quantity and quality to satisfy both basic consumption and hygienic requirements. This aspect will require further intensified research in order to identify the various policy-options available to formulate an appropriate life-line tariff for the poor under the Sri Lankan conditions, which unnecessarily does not subsidize the rich, who can pay for the services they receive.

Operational efficiencies of the water supply systems should be improved, and the levels of non-revenue water in all projects should be significantly reduced from their current high levels. This aspect is a very important consideration for Sri Lanka, both for existing and new projects.

Water demand management programmes should be implemented to reduce the levels of the current consumptions. In addition to the proposed economic instruments, other possible alternatives should be considered (for example, education and communications) accelerate the use of demand management practices. It should be noted that the urban domestic water tariffs in Sri Lanka are still subsidized by the Government, and by cross subsidies between consumers, and also between various projects.

These various subsidies, however, have been steadily declining, especially during the past ten years. For the Greater Colombo Urban Water Supply schemes, the current Government subsidies include: 50 per cent subsidy for the foreign loan components; and 100 per cent subsidy for the Sri Lankan Government contributions that is available in the local funds. In other words, the Board is required to pay back to the Government only 50% of the foreign loans, at an annual interest of 10%, over a period of 24 years, with another two years of grace period, if considered necessary. Furthermore, the Board returns the funds to the Government in Sri Lankan rupees: the Government assumes the entire foreign exchange risk, which could be quite substantial under many conditions.
Source: Biswas and Tortajada, 2003, Asian Water

the analyses carried out at the Third World Centre for Water Management, it now appears that the primary institutional paradigm is likely to be to improve very significantly the current performances of the public sector institutions. This may not be an easy task, but based on the experiences in a few developing countries, it is a doable task.

For instance, the experience of Sri Lanka is worth noting. The country's national water supply & sewerage policy has facilitated institutional reform in urban water sector (see Box), which is leading to improved performance of utilities. The country's water tariff had steadily gone up; the monthly per capita water consumption reduced; staff efficiency increased; outsourcing of certain services, like meter reading, increased; and revenue collection increased (Biswas and Tortajada, 2003). Equally, the private sector will play an important role within this new institutional paradigm, but not as the managers of large concessions as exhorted in the past, or expected at present, but as providers of specific services like meter-reading, billing, bill collection, leak detection and repair, vehicle management, construction of desalination plants on a BOT basis, etc.

Paradoxically, one major direct benefit of the promotion of the private sector as the preferred institutional paradigm of urban water management in recent years has been significant and steady improvements in the performances of public sector bodies in many areas. Such improvements can be seen in the performances of the public water utilities ranging from the United States to several developing countries, including Sri Lanka.

BOT would work when the political system is by and large non-corrupt; governments/bureaucracy functions; but the urban local body lacks enough technical and managerial skills and financial resources. Obviously, BOT contracts and "concessions" are necessary when a new water supply system is to be built and not when a functioning system already exists. Whereas in the case of large urban local bodies, wherein the technical and managerial skills are present, but administrative/institutional capabilities for direct contact with the communities are absent, private sector participation can be sought for provision of basic services. They can include: detection of illegal connections; installation of meters, taking meter readings, billing and collection of water charges.

One important issue with meter reading is the high corruption and false readings. The occurrence of such practices, wherein the meter readers collude with the consumers, is found to increase with increase in length of posting of the staff in a particular locality. In order to counteract the occurrences of such problems the meter-readers should be rotated very frequently in terms of the areas they cover, so as to ensure the potential of un-authorized incomes is significantly reduced, or even totally eliminated. For example, such very frequent rotations are practiced in Singapore, where corruption for meter reading has been virtually reduced to zero (Biswas and Tortajada, 2003).

In situations where the upkeep of the system is poor or the agency is lacking committed human resources to run and maintain the system, leading to poor physical performance, an O & M contract could be made to a private agency. The reasons could be many. One is unionization of the labourers engaged in plumping, pump operation, cleaning of sewer and drains, and metering. The other reason is lack of adequate technical and skilled manpower as the utility may not like to hire additional staff. Here, the payment is normally fixed. In order to create incentive among the private agencies to save water, the payment could be linked to the number of water supply connections being serviced. Such contracts are made in such instances where the private agency does not have to make major capital investments for sourcing water, or building the basic distribution infrastructure etc.

Where major investments are to be made, and the government has the capacity to make those investments, lease agreement is a good proposition. Here, the use of private agency should be to get highly skilled manpower for specialized services such as design and operation of sophisticated wastewater treatment systems, desalination systems etc. In other instances, the improvements in institutional arrangements for the public utility need to be tried out. This could be for tapping financial resources; adopting pricing policies;

Overall, the decision to privatize urban water supply should involve the following consideration: political stability and power of the government; effectiveness of overall governance; the overall financial condition; the ability to raise finances from external sources; infrastructure conditions; and the institutional capability (policies & legal framework; administrative capabilities). Depending on the situation vis-a-vis these, the mode of private sector involvement could be worked out.

### 10.5.3 Appropriate Staffing of Urban Water Utilities

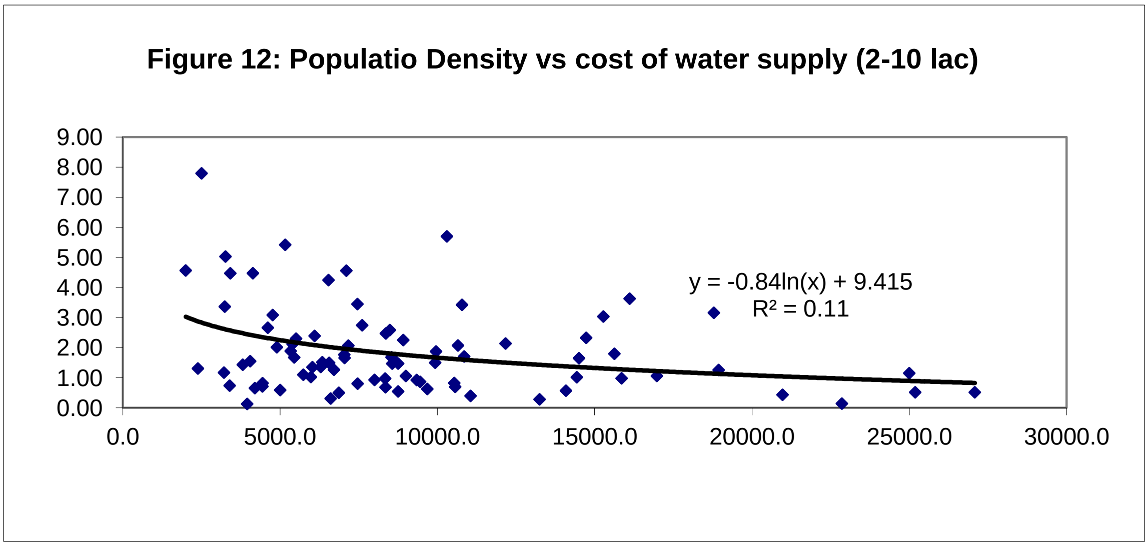
Appropriate staffing is crucial for strengthening the organizational capabilities of urban water utilities. Appropriate staffing is not only about placing adequate number of staff, but also about keeping people with the right kind of disciplinary backgrounds. Now, two utilities offering the same level of services in term of number of consumers served and the amount of water, wastewater and solid waste handled may be requiring different levels of staffing. This is because there are many physical and socio-economic factors influencing the staff efficiency, which are not within the control of the utility. Hence, a staffing norm based on simple criteria of the size of population to be catered will be improper. For that, the various factors that influence the physical, management and economic performance of the utility need to be identified. Based on these factors, sound criteria and norms for staffing can be worked out. These factors are discussed in the subsequent paragraphs.

#### Factors Influencing Management Performance

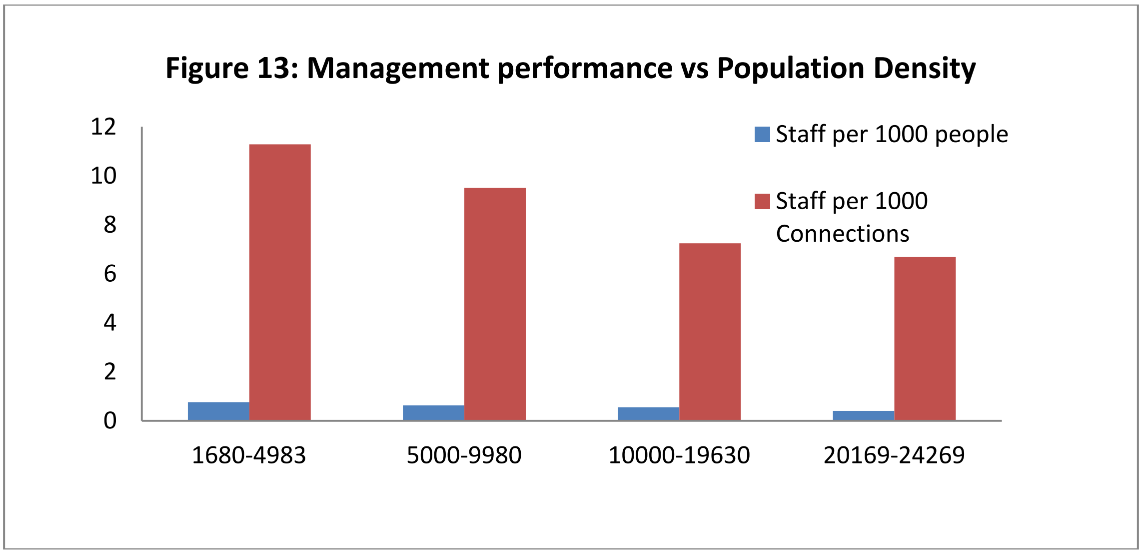
The managerial performance of the urban water utility (staff performance) in terms of provision of water supply, sewerage collection and treatment, solid waste disposal etc is a function of the institutional regimes, especially the incentive structures; and training and skill development etc. But, it is also a function of the characteristics of the urban area, which is influenced by the way they areas are planned. In an urban area with high density population, the human resource required to maintain certain level of service with respect to water supply would be much less than that in another urban area where population is quite scattered.

Number of staff per '000 connections and number of staff per '000 people are indicators of management performance or efficiency. Lower the figure, higher the efficiency.

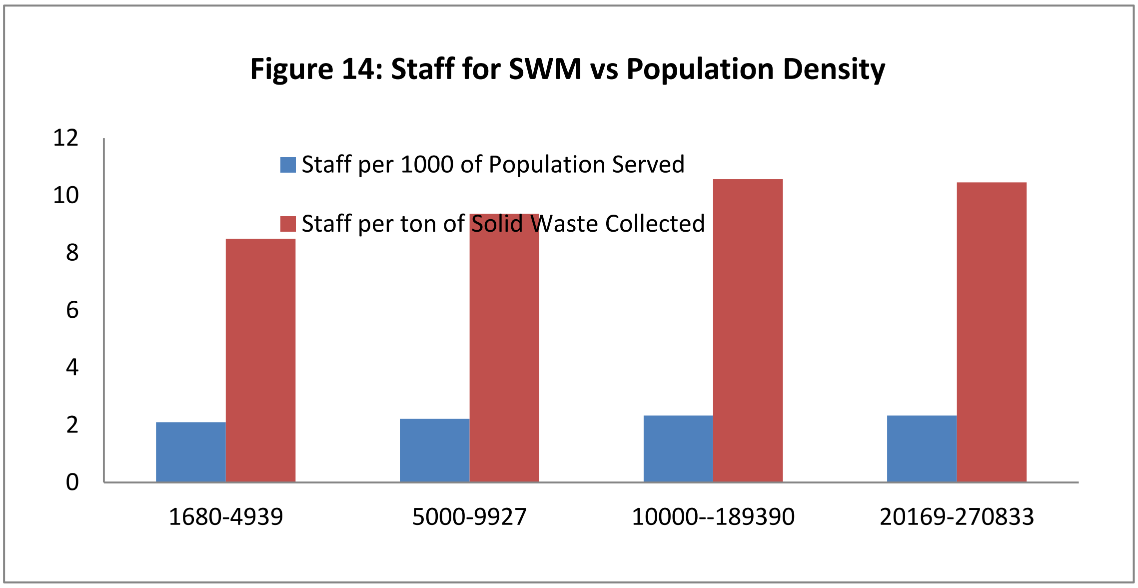
Our analysis using data from 301 towns/cities show the following: urban population density influences the cost of production and supply of water inversely, i.e., higher the population density, lower would be the cost of production and supply of unit volume of water. This is because of the lesser amount of water supply infrastructure would be able to supply water to a larger population when the population density is large. Nevertheless, a regression between population density (which ranges from nearly 5000 people per sq. km to 30,000 people per sq. km) and the cost of production and supply of water shows no major trend (Figure 12). This is because the cost of production & supply of water is also influenced by the water endowment in the town/city. Lower the water endowment, higher was the cost of production & supply of water as shown in the analysis in Section 6.1.




Another interesting finding was that the population density to an extent determines the number of staff required to provide water supply to a given population. Our analysis shows that higher the population density, lower the number of staff required to provide water supply to 1000 people and also the 1000 connections (see Figure 13).



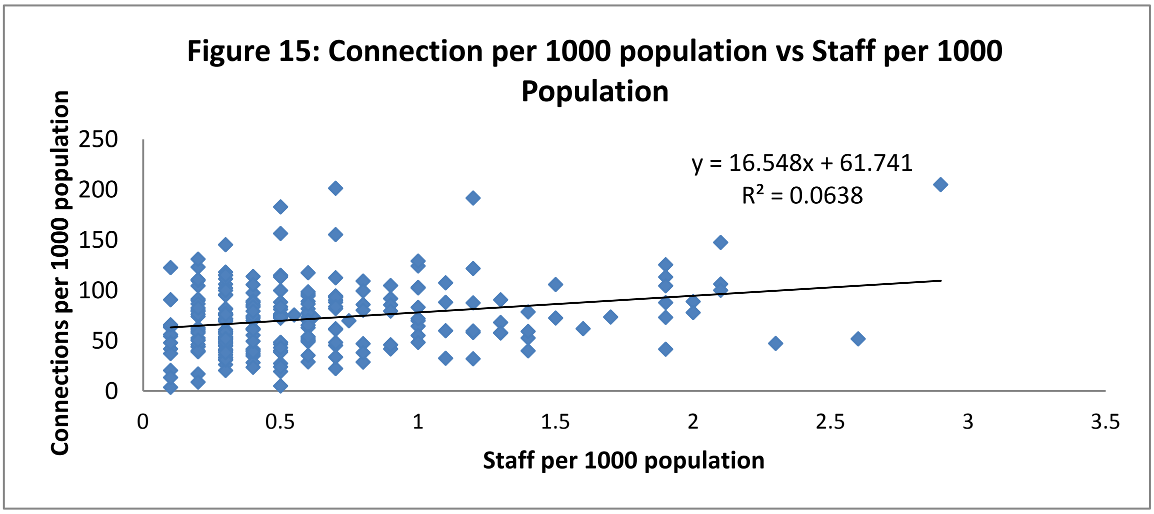

Contrary to what was found in the case of provision of water supply, in the case of solid waste disposal, the relationship between urban population density and the number of staff required to collect & dispose one ton of solid waste was opposite. Higher the population density, larger number of people were required to mange solid waste. Here, we have only considered the towns and cities which have a collection rate of more than 80 per cent as it is understood that maintaining collection efficiency up to a certain level, and maintaining a certain level of performance would normally require more people. This could be because of the fact that in densely populated areas, it would be difficult for the municipal staff to move the machinery for transporting the solid waste (Figure 14). Similar trend was found for cities with population concentrated in small geographical areas.




The foregoing analysis suggests that cities with high population density will enjoy certain advantages in terms of being able to manage the water supply affairs for the same level of connected load with lesser number of staff. At the same time, they will be at a lesser advantage when it comes to managing solid waste collection and disposal.

### Factors Influencing Institutional Performance

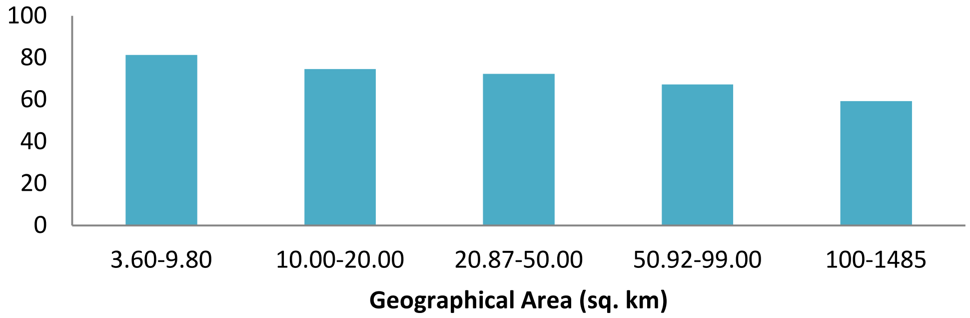
Number of connections per unit size of the population is a good indicator of institutional performance of urban water utility (Arghyam/IRAP, 2009). Analysis with number of staff per thousand population and number of connections per '000 population shows that larger the staff size, higher the institutional performance, expressed in terms of number of connections per thousand persons. Nevertheless, the relationship is quite weak here (R2=0.06) (Figure 15). This is because of the fact that there are factors other than staff which influences the ability to provide water supply connections such as urban population density. As we have seen in Section 10.5.4, with the same staff strength, cities with higher population density will be able to provide water supplies to a larger number of people.



## Factors Influencing Physical Performance

Another interesting observation is that increasing area coverage in water supply reduces the physical performance. This validates a well-known theory in water supply engineering, and is perhaps due to greater length of the distribution lines per unit volume of water transported and the greater pressure to be maintained in the waterline due to higher pressure losses. Both length and pressure increases the technical losses in water supply pipelines (source: Growing towards more efficient water use: Linking Development, Infrastructure and Drinking Water Policies United States Environmental Protection Agency, undated). Figure 16 shows the average percentage of accounted for water, i.e., the inverse of unaccounted for water for cities with different geographical area. It shows that with increase in geographical area, the % accounted for water reduces, or % UFW increases. But, it may be mentioned here that the UFW figures used in the chart also include the administrative losses, in addition to the technical losses, i.e., the leakage.

**Figure 16: Percentage Accounted for Water in Cities of Different Area Ranges**




## Staffing Norms for Urban Water Utilities

One way to determine the norms for fixing staff size and strength of urban water utilities is to look at the norms of those utilities which are performing well. As we have seen in the previous analysis, there are many complex factors influencing the performance of urban water utilities such as urban population density and geographical area on which the utility does not have much control. Hence, an alternative is to compare the staffing of utilities, which have differential performance, but are not markedly different in some of their physical attributes mentioned above. Intuitively, the performance of utilities in metros is much better than that of cities and smaller towns, in terms of their physical performance (water supply, sanitation coverage and wastewater treatment and disposal and solid waste disposal), fund availability and financial health. If it is so, then the staffing of utilities falling in that category can be used as a benchmark for other utilities. Here, we have used the data for 301 towns and cities which fall under three different categories, viz., metros, Class I cities and Class II cities.

Table 34: Comparison of Average Physical, Financial and Economic Performance and Human Resource Profile of Utilities under Different Classes

| Sr. No | Attributes | Performance Indicators | Status in | | |
|---|---|---|---|---|---|
| | | | Metros | Class I | Class II |

| | | | | | |
|---|---|---|---|---|---|
| 1 | **O&M charges** | Total water supply (MLD) | 591.7 | 47.3 | 7.7 |
| | | per capita WS (lpcd) | 160.2 | 111.9 | 86.3 |
| | | Total O&M in lac | 6667.3 | 322.4 | 69.4 |
| | | O & M cost per MLD | 8.9 | 6.92 | 10.08 |
| | | O & M cost per unit of water | 3.25 | 2.53 | 3.68 |
| | | O & M cost per capita | 518.6 | 274.9 | 3223 |
| 2 | **Water Supply (%)** | % of population covered | 94.6 | 90.2 | 89.2 |
| | | Demand achieved (%) | 96.4 | 78.4 | 78.6 |
| | | Supply gap (%) | 3.6 | 21.6 | 21.4 |
| 3 | **Sanitation** | Population covered (%) | 51.73 | 47.44 | 51.1 |
| | | Area covered (%) | 45.4 | 40.7 | 48.5 |
| 4 | **Solid Waste** Management | Waste generated (tons) | 1598.0 | 136.4 | 27.20 |
| | | Waste collected (ton) | 1454.0 | 116.5 | 20.5 |
| | | % of waste collection | 88.9 | 86.3 | 79.5 |
| 5 | **Staff** | Water supply staff for 1000 people | 0.73 | 0.55 | 0.63 |
| | | Staff per 1000 connection | 12.44 | 9.25 | 8.76 |
| | | SWM staff/1000 population | 2.20 | 1.99 | 1.87 |
| | | Technical staff in water supply | 238.5 | 43.82 | 11.77 |
| | | Total staff in WS | 978.5 | 202.85 | 60.51 |
| | | Technical staff (%) | 21.8 | 19.1 | 17.2 |
| 6 | **Metered Connections** | Total tap connections | 4667326 | 3303030 | 608735 |
| | | % of metering | 51. 9 | 40.9 | 33.6 |
| 7 | **UFW** | Water Supplied(MLD) | 603.7 | 45.1 | 7.7 |
| | | UFW in MLD | 143.24 | 7.42 | 0.78 |
| | | UFW in % | 22.9 | 13.1 | 10.9 |
| 8 | **Treated water** | No. of treatment plants | 92 | 255 | 78 |
| | | % towns covered | 95.5 | 62.1 | 47.7 |

Source: authors' estimates based on data provided in NIUA (2005)

From Table 34, it is clear that there is a general trend emerging with respect to the performance of urban water management system. Among the three different categories of cities/towns, the overall performance of urban water utility is best for metros. While doing this, we have not considered the economic and management performance, and have included the physical, financial and environmental performance. The reason for this is that comparison of such performance indices across the cities and towns would make sense only if their physical performance is comparable. Otherwise, such comparisons will be useless. For instance, a city will be able to provide water at a very low cost (in terms of amount of water supplied with unit expenditure on O & M, which is the inverse of the O & M cost per unit of water) if it decides to supply water to only a certain proportion of the population or if it decides to limit the supply levels, thereby deferring new infrastructure projects for supply augmentation and reducing costs. Similarly, a city will be able to manage a system with fewer staff if it decides to not to extend the services to the entire jurisdiction of the urban administration

Hence, the following attributes are considered. 1. Water supply coverage. 2. Demand coverage. 3. Sanitation coverage. 4. Wastewater treatment. First of all, the water supply coverage is highest for metros, whereas the supply gap is lowest. Rate of solid waste collection is also highest for them. Sanitation coverage is highest for metros both in terms of population covered and the proportion of the geographical area covered.

On the other hand, if we look at the factors that influence the performance of the utility, such as staffing, and the investment towards operation and maintenance of the systems, the metros score high. The cost of maintenance per unit volume of water is highest for metros. So is the number of staff per 1,000 persons covered and 1,000 connections. From the analysis presented in a preceding section, we have seen that the better staffing and better investment for O & M help the utilities to perform better in terms of achieving better water supply coverage in terms of number of connections per unit size of population. The analysis showed that higher the number of water supply staff per 1000 population, higher the number of connections for that population. The foregoing analyses lead us to the following points: 1] raising the performance of the utilities of smaller towns from the present levels to that of the metros would require increasing their staff strength and improving their staff composition; and 2] further improvement in performance of the utilities would require higher staff strength.

It goes without saying that the performance of metros is still not ideal and hence their staffing. As seen from the table, their sanitation coverage (54%) is far below the desired level of 100 per cent, and wastewater treatment is still partial. Many metro water boards undertake only primary treatment of wastewater, while some undertake secondary treatment of a portion of the wastewater. We do not have any data on this at present. Achieving higher levels of sanitation coverage would require more staff in that line department. Similarly, covering more area and population under sewerage system and drainage would require more staff for planning & design, and operation and maintenance. So is the requirement of staff for metering, billing, water tariff collection, and checking the functioning of meters, leak detection, leakage reduction etc. Nevertheless, it is important to mention here that the utility can outsource some of these functions, particularly, installation of meters, billing, water tariff collection, checking of functioning of meters and meter repair, and hence do not need to keep additional staff for performing those function.

But, as we have seen earlier, staffing is a function of the managerial efficiency. The management performance, however, is a function of several physical attributes such as density of urban population and the geographical spread of the city. While there could be difference in the management performance of utilities across different categories of cities, which in turn would upset our estimates of the staffing norms, there is hardly any reason to believe that the management performance of smaller towns is better than that of large cities, which are the reference points for most of our norms. In fact, all the anecdotal evidences suggest that small towns suffer from problems of inefficient management due to lack of adequate qualified manpower and tools.

Table 35: Staffing Norms for Different Line Functions in Urban Water Utilities

| Sr. No | Staff Category | No. of Persons for '000 population (current) | Most desirable | Suggested amendments in norms |
|---|---|---|---|---|
| 1 | Water Supply & Sewerage | 0.73 | 1.00 | Can be 10% less if urban population density is very high |
| 2 | Wastewater Treatment | NA | 0.50 | |
| 3 | Solid Waste Collection & Management | 2.3 | 2.50 | Can be 10% more if the urban population density is very high |

Source: based on authors' analysis

There are three major areas of improvements in urban water supply, which will have significant implications for improving the staff efficiency in managing urban water supplies: 1] implementation of SCADA; and 2] computerized billing; and 3] automation of metering.

In water supply systems, Supervisory Control and Data Acquisition System is meant for operational control of the system for optimum performance and better efficiency. It is done by logging and transferring of data relating to reservoir levels, pump discharge, pump efficiency, water pressure, water quality etc. to a master control facility. For instance, if there are several reservoirs which source water, their operation can become complex as it would require coordination of the work by various operators on a real time basis. Under such circumstances, automation of monitoring of water level data in the reservoirs from one point can facilitate smooth operation of multiple reservoirs in an integrated manner. By this, the utility can save the staff time required for physical supervision and monitoring of performance of reservoirs and gate operations, and coordination amongst multiple locations.

Also, use of sensors in SCADA can be used for continuous monitoring of quality of water in the distribution system, thereby avoiding the need for periodic collection of water samples from different points in the distribution and service lines and their testing. It could also monitor pressure development in the pipes, thereby guiding valve operations and averting the danger of pipe bursts. In India, SCADA was first implemented in Gujarat for the 450km long drinking water supply pipeline for Kachchh and Saurashtra based on Narmada and Mahi schemes (Talati and Kumar, 2005). SCADA is currently implemented in urban areas of Goa (Wachasundar, 2007) and Pimpri Chinchvad Municipal Corporation (PCMC).

## 10.6 Training of Human Resources

Most urban water utilities today perform very limited functions. In the case of small towns, it is mostly limited to supplying treated or partially treated or untreated water to the urban consumers. Here, the orientation is mostly on conventional water supply systems. But, there are many non-conventional water supply systems, which can provide future water supplies in many cities and towns such as rainwater collection tanks, and desalination systems. The conditions under which they are suitable, the hydrological opportunities they offer and their economic aspects need to be understood by the water supply professionals.

In most cities, wastewater is not treated at all. In some cities, waste water is partially treated. Similar is the situation vis-a-vis storm water generated in urban areas. Neither there is adequate system for storm drainage and disposal. In many towns, the storm water from most parts of the town/city is collected by the sewers. They need to be newly introduced as part of IUWM.

Planning, designing, building and operating wastewater treatment and reuse systems that take into account the range of socio-economic (land availability, land prices and demand for treated wastewater) and physical factors (climate, altitude and temperature) would also require good understanding of the theories in bio-chemical engineering, biology, environmental engineering and environmental economics, which are used in the design of wastewater treatment and reuse systems. It also would require familiarization with various wastewater treatment technologies now available, as these technologies are not in use in any of the urban areas in India. Providing for integrated storm water management would require sound understanding of the very concept of sustainable storm water management. All these would require training.

Over and above, the various emerging concepts in urban water management such as demand management, community participation in urban water management etc., which are part of urban water cycle management, and the technical and economic tools for achieving them need to be understood at various levels such as the bureaucrats in the municipality/ corporations, the technical staff handling urban water systems within the municipality/corporation or the utility professionals, the representatives of the people (councillors etc.).

But, what is important is that the types of training which the primary stakeholders (urban communities) require for building their capacities for participating in urban water management would be different from those which the utility officials require or the governing body of the municipal body require for implementing them. Generally, the officials of the utility would be concerned with different aspects of various technical, institutional and policy interventions. Again, there are too many topics to be covered. It is impossible to cover them in one training module, given the practical issues involved in attending long duration trainings for the participants, and the need for some time duration between one training event and another event to facilitate good learning. Therefore, it is important to split the training programme on urban water management into several modules on the basis of the themes and their utility for the stakeholders.

The idea is that themes, which are relevant for certain stakeholders only, can be appropriately targeted. Table 36 provides the list of different training modules, the topics which can be included under each module, and the target groups.

Table 36: Listing of Capacity Building Training Programmes at various levels and Module Contents

| Module No and Theme | Topics | Participants |
|---|---|---|
| Module 1<br>One Day Orientation programme-Town Level | 1. Importance of water security & environmental sanitation<br>2. IUWM and its scope for the town<br>3. Need for participatory approaches | TMC (ULB) Ward Councillors, Political leaders, WATSAN Officials, SHG reps, Private water vendors and operators, Local NGOs, implementing agencies of IUWM etc. |

| | | |
|---|---|---|
| Module 2<br>Project Launching Workshop<br>(Integrated Urban Water Management) | 1. Introduction to IUWM<br>2. Economics of investments in IUWM<br>3. IUWM Principles & Practices<br>4. IUWM framework and the key elements | TMC (ULB) Ward Councillors, Political leaders, WATSAN Officials, SHG reps, Private water vendors and operators, Local NGOs, implementing agencies |
| Module 3<br>Understanding existing urban water systems | 1. Survey of urban water infrastructure<br>2. Use of decision support systems (GIS) for water distribution planning; water supply system design<br>3. Use of expert systems for analyzing the resource dynamics, hydraulic efficiency estimation, and leakage detection | TMC (ULB) key officials, WATSAN Officials, Ground water department, river basin agency (if any) |
| Module 4<br>Community involvement and Participation | 1. Level of community involvement in water & sanitation activities<br>2. Role of community in IUWM<br>3. Legal rights/regularities of CBOs in IUWM | Representatives from community, TMC governing body members |
| Module 5<br>Urban water cycle management | 1. Water resource management (river, ponds, lakes, aquifer)<br>2. Water supply management<br>3. Water demand management<br>4. Analysis of urban hydrology (roof water catchments, storm water flows)<br>5. Efficient water use in urban areas & technologies<br>6. Water treatment & reuse potential<br>7. Water vending<br>8. Packaged drinking water & and its SWORT analysis | TMC (ULB) key officials, WATSAN Officials, GWD, CBO reps, Land use board, Pollution control board, IUWM implementing agencies etc. |
| Module 6 (2 parts)<br>1) Waste water<br>2) Solid waste | 1. Generation of waste water<br>2. Treatment of wastewater<br>3. Reuse of wastewater (potential & threats)<br>1. Solid waste management and recycling | Sewerage board, SWM agencies, Publics, |
| Module 7<br>Sustainable Storm Water | 1. Accounting of storm water<br>2. Using storm water for town | TMC (ULB) key officials, WATSAN Officials, CBO reps, |

| | | |
|---|---|---|
| Management | needs: water quality aspects<br>3. Storm water management and reuse options | Private water vendors and operators, implementing agencies.etc |
| Module 8<br>Eco-sanitation and industrial waste management | 1. Adoption of eco friendly toilets /sanitation facilities to reduce water consumption and contamination<br>2. Newer techniques to control industrial wastes | TMC (ULB) key officials, WATSAN Officials, CBO reps, industrial entrepreneurs and related officials from departments, pollution control board, health departments |
| Module 9<br>Institutional change | 1. Existing organizational set up, and governance systems<br>2. Institutional capacity building in UW Sector<br>3. Instruments for capacity building<br>4. Institutional reforms<br>5. Public-private partnership and relevant models<br>6. Community participation in UWM, and the roles | TMC (ULB) Ward Councillors, Political leaders, WATSAN Officials, CBO/SHG reps. |
| Module 10<br>Water Pricing & Water demand management | 1. Price elasticity of urban water demand<br>2. Economic principles in pricing urban water<br>3. Metering of water supplies<br>4. Technical issues in metering | TMC Governing members, WATSAN officials, CBOs |
| Module 11<br>Setting up of MIS | 1. Generating data on urban water systems & supply<br>2. Setting up database on GIS platform<br>3. Generating management information systems | WATSAN Officials, GWD,TMC (ULB) key officials, department officials from irrigation, Urban planning, |
| Module 12<br>Operation & Maintenance of Water supply and sewerage systems | 1. Role of service providers for O & M of urban water systems<br>2. Preparation of contracts<br>3. Contract laws and their provisions relevant for water supply and related services | TMC(ULB) Ward Councillors, WATSAN Officials, implementing agencies of IUWM, private service providers etc. |

| | | |
|---|---|---|
| Module 13<br>Rain Water Harvesting | 1. Urban bylaws for promotion of RWH tanks<br>2. Use of rainwater for meeting urban water needs: quality aspects<br>3. Design of rainwater collection systems | Key experts from various Departments and agencies related to environment, Agriculture, WATSAN, Urban development, Social development etc. TMC (ULB) Ward Councillors, CBO/SHG reps, Local NGOs |
| Module 14<br>Ground water recharge | 1. Role of groundwater in urban water management<br>2. Key characteristics of groundwater in urban areas<br>3. Groundwater management<br>4. Artificial groundwater recharge: sources, and techniques | Key experts from various Departments and agencies related to environment, Department officials from Irrigation, Agriculture, WATSAN, Urban development, Social development etc. TMC (ULB) Ward Councillors, , WATSAN Officials, CBO/SHG reps, farmer's associations, Local NGOs, land use board |
| Module 15<br>Financial Management | 1. Tools for improving the finance of water utilities (pricing, mobilizing funds)<br>2. Improving revenue collection systems<br>3. Online payment of water charges, and grievance systems | TMC (ULB) key officials, IUWM implementing agencies etc. |
| Module 16<br>Risk management | 1. Prevention, mitigation and preparedness for water &climate related disasters<br>2. Extension of WATSAN facilities according to the growth of population& migration | Disaster management units, TMC &WATSAN officials, Urban planning department |

## 10.7 Institutional Arrangements for Urban Water Management

### 10.7.1 Administrative Arrangements for Urban Water Management in India

The administrative arrangements for urban water supply for different types of cities/towns in different Indian states are shown in Table 37. In most states, the capital works in small cities are undertaken by a special state level agency, whereas the operation and maintenance (O & M) is carried out by the municipal department which maintains a thin staff. In large municipalities, both the tasks are performed by the municipal departments.

Only in the case of large corporations, there is a specialist agency looking after the entire UWS&S management. In some states like in Kerala, the entire work is performed by a specialist state level agency in the urban centres of the entire state, which has its offices in all the small and large towns and cities equipped to perform UWS &S function.

There are two sets of issues here in having two different agencies. *First*: the agency which is entrusted with the responsibility of building the infrastructure is often alien to the local conditions of the urban area, including the topography, the road, pipeline and drainage networks, the new developments, the areas susceptible to water-logging etc. As a result, the designs are not very efficient. This issue was raised by the technical staff of three of the municipal departments in Gujarat, namely Kalol, Nadiad and Khambat.

*Second*: the municipal departments of small municipalities do not have permanent technical staff for managing their water supply & sanitation affairs, and is ill-equipped to run the system as often the technical staffs are on deputation from a state department (like Gujarat Water Supply and Sewerage Board or the Punjab Public Health Engineering Department). These deputed staff members are not permanently based in one municipality and their postings are often subject to frequent transfers. This makes it hard for them to understand the system thoroughly. This leads to a related problem. The technical staffs dealing with UWS & S do not have any special incentive to perform, as their performance is not evaluated by the municipal authorities, but the senior officers sitting in the state head quarter of the specialist agency. These points partly explain the low level of performance of the smaller towns as compared to the large cities.

The issue here is not about the urban local body not having adequate staff, but that the agency which is concerned with operation and maintenance should be equipped to plan, design and built or supervise the construction of the water infrastructure. Further, such agency should have a permanent base in the locality.

Table 37: Administrative Arrangements for Urban Water Supply in Different Indian States for Different Types of Urban Areas

| Name of State/ City | Jurisdiction | | | | | Responsibilities | | Type of Agency |
|---|---|---|---|---|---|---|---|---|
| | **Metros** | **Large Muni. Corp** | **Large Cities** | **Small Cities** | **Entire State** | **Capital Works** | **Operation & M** | |
| Bangalore, Chennai, Hyderabad, Kolkata | *** | | | | | | | Specialist Metropolitan Agency |
| Delhi | *** | | | | | | | Specialist Municipal Undertaking |
| AP, Gujarat, Maharashtra, Tamil Nadu | | *** | | | | *** | *** | Municipal Department |
| Gujarat | | | | *** | | *** | | SAS* |
| Do | | | | *** | | | *** | Municipal Departments |
| Andhra Pradesh | | | | *** | | *** | | PHED |
| Do | | | | *** | | | *** | Municipal Authority |
| Do | | | | | | | | |
| Karnataka | | | | *** | | *** | | SAS |
| Do | | | | *** | | | *** | Municipal Authority |
| Kerala | | | | | *** | *** | | SAS** |
| Maharashtra, Tamil Nadu, Uttar Pradesh | | | | *** | | *** | | SAS |
| Do | | | | *** | | | *** | Municipal Authority |
| Rajasthan | | | | | *** | *** | | PHED |
| Do | | | | | | | *** | Municipal Authority |
| Uttar Pradesh | | *** | | | | *** | | City-level specialist agency |
| Do | | *** | | | | | *** | SAS |
| Haryana | | | | | *** | *** | | PHED |
| Do (Only Faridabad) | | *** | | | | *** | | Municipal Corporation |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Punjab | | | | | *** | *** | | SAS**** |
| Do | | | | | *** | | *** | Municipal Departments |
| Chandigarh | | *** | | | | *** | | Municipal Body |
| West Bengal | | | | *** | | *** | | PHED |
| Orissa | | *** | *** | | | *** | | PHED |
| Pondicherry | | *** | | | | *** | | PWD |

*Gujarat Water Supply and Sewerage Board
** Kerala Water Authority
**** Punjab Water Supply and Sewerage Board

Large cities are those having a population of more than 2 lac people. Small cities have less than 2 lac population.

### 10.7.2 Institutional Development for IUWM

Improved IUWM will require engagement with a complex array of administrative, political, institutional, social, economic challenges in cities. There is a need, therefore to stimulate changes in policy and practice in urban water management within institutions, other levels of government and civil society. An underlying hypothesis is that without institutional change it will not be possible to achieve a paradigm shift towards more integrated management. The new paradigm is likely to require: Changes in holistic environmental thinking; Changes in institutional structures and frameworks; Change in use of means and resources; Changes in managerial methodologies and approaches & Changes in approaches to financial planning and management to include explicit attention to pro-poor and gender-specific strategies. Developing and managing institutional improvements is a difficult process.

Edwards (1988) has developed manual that provides practical and immediately useful information about developing and managing institutional change projects in the water supply and sanitation sector. He points out that institutional development projects should "*focus on the development of comprehensive organisational systems and the people within the system which make them work*." He goes on to say that '*the overall purpose of these projects is to achieve institutional learning or sustainability"* More recently there has been interest in the development of the 'Change Management Forum' (CMF) in India (www.cmfindia.org). The mission of this forum is to "*Promote institutional and organisational development and support reform of the urban water and sanitation sector through capacity building, knowledge sharing and promotion of partnerships*".

The CMF works through policy and decision makers from municipalities, water utilities and Pubic Health Departments to develop critical mass of change champions. Activities of the CMF include dissemination of information on best practices, knowledge resource products, introduction of performance indicators, and the development of a benchmarking database.

### 10.7.3 Institutional Integration

Planning and management of water resources involve complex considerations of the physical systems affecting water availability, and the socio-economic systems affecting water use-agricultural communities, industries, fishing, communities, urban areas, forest communities (Kassem, 1996). In order to integrate these complex aspects related to water resources management, comprehensive and complex systems such as river basins should be the unit for governance of water resources and not local systems (Klomp *et al.*, 1996; El-Ashray, 1993). Therefore, there is a need for building institutions at the level of river basins that are capable of balancing the current and future demands with the supplies, without threatening the hydrological and ecological integrity of the basin.

The functions of various institutions engaged in different aspects of water development and management in the basin will have to be integrated at the basin level to manage the entire water system comprising water resource system and water supply and use system in a comprehensive manner.

A single agency, river basin organization, is required to carry out water resource management functions at the level of river basins. Since water resource management needs at the local level widely varies across the basin, the role of the basin management institution will not be just in balancing the groundwater withdrawal and extraction at the aggregate level, ensuring release of water for ecosystems, and catchment protection/management. It also has to tackle problems such as excessive draw down in groundwater in certain localities, water pollution, excessive rise in groundwater levels, excessive seasonal drops in water levels, groundwater contamination and flood control. For this, a range of micro-level actions will be needed.

This calls for major reforms in the governance of water resources in the State. Laws will have to be enacted that provide for creation of RBOs and enforcement of water rights. Organizations need to be set up for carrying out for the following line functions to build institutional capabilities for water management, namely, water resource monitoring, water resource evaluation and planning, execution of water development and management schemes, and water allocation.

Apart from carrying out integrated water resource management activities, the RBO can be vested with the powers for allocation of rights to use water from the basin to various sectors of use including the urban water utility. In this process, they become the coordinating institution for various line agencies dealing with water related services for different sectors of use, and can integrate their activities at the level of river basin. The service agencies will have to obtain the volumetric water use rights from the RBO.

Many developed countries such as Australia, France and Japan have established river basin organizations. The Murray-Darling Basin Ministerial Council of Australia, which is concerned with natural resources (land, water and environmental resources) management, which was encompasses parts of four sovereign states of the country. The role of the Council is to set policy and define broad directions for the management of natural resources in the basin. It is supported by the Murray-Darling Basin Commission to execute its policies. It is charged with efficiently and equitably managing and distributing the water resources of River Murray. It also advices the Council to achieve sustainable, long term water utilization.

The technical responsibilities of the Commission, which has two commissioners from each one of the participating states, are: River Murray Management; water quality, land resources, nature conservation, and community involvement. The environmental responsibilities include: coordinating action to preserve the native fish and riverine environment, and coordinating the management of wetlands on the River Murray floodplains. The communication team of the Commission produces materials to raise public awareness of the Murray-Darling Basin and the management of its natural resources, and for this they coordinate with the education department, government agencies, community resource centres and the media (World Bank/GOI, 1998).

In France, the river basin organizations were created for allocation of water rights among different sectors of use and users within sectors, as well as for performing water resource management functions within the basin area. France has six river basin organizations. The water tax rates are decided on the basis of the type of use, and the tax paid by the users is used for implementing basin management activities (Ladel, 2003). Many Asian countries are in the process of creating RBOs as institutional tools/mechanisms for allocation of water resources across sectors and regions.

### 10.7.4 Governance System for Water Resource Management at the basin level

A River Basin Organization (RBO) shall be constituted on three design principles. 1. The operational boundaries of the governance units created for effective management should match with the hydrological system boundaries. 2. The institution that is responsible for enforcing norm and regulations on water use (including pollution) should be responsible for investment in water quantity and quality management. 3. The governance/management structure will integrate local water management interventions with larger basin management actions and promote involvement of user groups/ communities in the governance and management. The proposed management structure is a vertically integrated hierarchy of organizations from watershed to sub-basins/river catchments to river basins.

The overall governance of the RBO shall be provided by a G*overning Council*, which will be drawn from the individuals and civil society organizations concerned with water resources. The *Governing Council* will take the major policy decisions such as: [1] the extent of utilization of the basin's water resources for various beneficial uses for the present and future generations and water imports; [2] definition of beneficial use rights, [3] fixing of water taxes/water fee; special incentives for sustainable storm water use which also helps flood and water quality protection; and [4] overall resource management objectives. This can be more or less in line with the water parliaments created for French RBOs.

A Stakeholder Forum can assist RBO through periodic interactions with the Governing Council**.** It can include all groundwater users in the upper catchments, irrigators in the lower catchments including canal irrigators, domestic water users in rural areas, cattle rearing communities, municipal water users, industries, in stream users of water from the trunk river and tributaries, the fishing communities engaged in fishing from the reservoirs, local ponds and rivers, ecologists who are concerned with watershed conservation, riverine and flood plain ecosystem and estuary, and environmentalists concerned with water logging, soil salinisation and water pollution in the rivers and groundwater.

The management unit of a RBO can implement the policy decision taken by the governance unit. This is parallel to the French Water Agencies. It has to perform the following tasks: [1] planning of various water resource management activities to tackle specific resource degradation problems; [2] water balance studies and water budgeting; [3] water allocation; [4] recovery of water taxes (including pollution tax) and payment of special incentives for carrying out storm water management activities; and, [5] monitoring of basin's water resource availability and its quality. In the governance system proposed, the water resource management functions and functions relating to management of water-related services are to be separated and are to be performed by different agencies. There would be enable "clarity of role" between river basin organization and the water service agencies.

The overall regulatory functions of water quality management for the river basin, the river and the groundwater should lie with the pollution control board, if the RBO undertakes pollution control activities. But, different models are available. In France, for instance, the RBO performs the regulatory functions, and delegates the task of setting up treatment plants to private agencies. The RBO carries out basin planning, collect fees for abstraction and pollution of the water resources, and also provide subsidies to local government for wastewater infrastructure (Chéret, 1993). The institutional design principle to be followed is that the agency doing regulatory functions of Water Quality Management and the agency which carries out pollution control measures should be separate.

The direct regulation of industries and other agent polluting water bodies should be resorted to only when we know that pollution control is technically feasible and economically viable for individual polluters. Otherwise, it is more appropriate to levy taxes from the polluters and use the funds for investing in pollution control measures. The reason is economies of scale might be possible through such approaches, reducing the cost of pollution treatment per unit level of toxicity. The latter one is more important for large number of small industries in a locality. This is discussed under section 10.7.9 under legal and regulatory framework for urban water management and water quality management.

### 10.7.5 Organisational Structure of River Basin Organization

To encourage basin community's participation in all resource management actions, a river basin organization should have a decentralized institutional format. The RBO can execute various activities through its various operational units, namely, Sub-basin Organizations, Urban Water Councils (UWCs), and local water management institutions namely, Watershed Management Committees and village level water users associations. The management unit of the Catchment/ Sub-basin organization can be constituted by a small group of professionals specializing in subjects related to water more or less similar to that of the basin level organization. The *Sub-basin Organisations* will be responsible for evolving water resource management plans for the catchment/sub-basins concerned, within the context of the basin management plans.

At the next lower level in the organizational hierarchy would be the local water management institutions. In the case of watersheds in the upper catchment areas, the watershed committees can perform the role of the local water management institution. The representatives of VWUAs will constitute them. The WCs can carry out detailed planning of various resources management activities at the watershed level. Today, planning for different watersheds within a river basin or large catchment is done in an uncoordinated fashion, and does not look into the larger basin interests. There could be a "trade off" between local interests and the interests of downstream areas. For instance, intensive water harvesting to impound water in upper catchment areas could reduce the flows into downstream water systems if the basin is "closed[31]" (Kumar *et al.*, 2008). The VWUAs will be the smallest operational unit in the governance/ management system and lowest in the organizational hierarchy[32].

The group of citizens' representatives will provide governance of the UWCs. A team of professionals with background in public health engineering, civil engineering, water treatment, water chemistry, water economics and urban planning can provide the managerial support. The necessary finance for implementing the activities will be mobilized by the UWCs directly or by the management unit of the RBO from the urban water users, including municipalities and industries. The UWC, which is a wing of the RBO, should carry out pollution treatment in urban areas. The resources for the same has to come from the urban water utility, which pays the environmental cost component of the water charges being recovered from the consumers, to the RBO.

It is also possible that the RBO/ UWC engage private service providers for carrying out wastewater treatment. In that case, the role of UWC would only be limited to that of a regulatory body, and not an executive body. The framework for community regulation of water quality in urban areas is discussed in Section 10.7.9.

### 10.7.6 Allocation of Water to Users and User Groups

There are no well-defined water rights in India and right to use water[33] is attached to land ownership rights (Singh, 1995; Saleth, 1996). This is a major cause of inefficient,

[31] A basin is said to be "closed" if all the renewable water in the basin is diverted for beneficial uses and eventually gets used up.

[32] The local level users of water including farmers and irrigators, dairy farmers and live stock-rearing communities, and representatives of rural households, especially women, will constitute the VWUAs. In situations where a watershed is falling within a village, the village water management institution will be same as the watershed management institution. In the plains, the VWUAs will perform the role of local water management institutions.

[33] Not applicable to water from designated catchments of river basins, which are already appropriated by the government agencies.

inequitable and unsustainable use of water, particularly groundwater. But, many developed and developing countries had gone for institutional reforms in the water sector in response to growing water scarcity. Establishment of tradable water rights is the cornerstone this reform. Some such countries/regions are Western United States, Chile, South Africa and the Murray Darling basin in Australia (based on Haisman, 2005; World Bank/GOI, 1998; Thobani, 1997). Equity in access and physical sustainability of resource base are important considerations for establishing institutional regimes for sustainable water use (Kumar, 2000; IRMA/UNICEF, 2001). Hence, realistic assessment of total water resource availability, renewable freshwater and economically accessible water resource in different regions/basins will be the corner stone of establishing tradable property rights regimes.

## Allocating groundwater

In areas with extensive alluvial deposits[34], the total groundwater storage is many times more than the groundwater which is accessible economically. The economically accessible groundwater is much more than the replenishable groundwater. Since sustainability considerations over-ride economics, only the renewable portion of the water should be brought under the property rights regimes. But, in hard rock areas of India, the economically accessible groundwater will be less than the renewable groundwater resources as these regions have very little static groundwater. But due to "well interference", which is a characteristic feature of hard rock areas, the actual "abstraction quota" that can be permitted to any farmer and that does not deprive the neighbours of their rights will be much less. In order to internalize this phenomenon of well interference, and make the rights "non-correlative" or exclusive, the communities can devise mechanisms.

## Allocating surface Water

The allocation of volumetric use rights in surface water should be determined primarily by two important considerations: the annual runoff (x), and the amount of water needed for ecosystem services (y). The amount of water that can be allocated for various competitive uses annually will be (x)-(y). Some flow will have to be maintained in Sabarmati river trunk in order to flush out the effluents and to maintain the riverine ecosystem during the non-monsoon period. But for all practical purposes, the surface water use rights allocated to the service agencies will be decided by the total volume of water that can be harnessed by the existing storage and diversion head works built by these service agencies.

In water rights allocation, there are two issues: 1] inter-sectoral water allocation; 2] intra-sectoral allocation. Once the quantum of resources to be brought under private property regimes within a basin is assessed, the criteria for allocating water rights among different sectors of use and among different users within each sector can be evolved.

One important criterion for allocation of water use rights could be the per capita renewable freshwater availability. In basins where it is low, lion's share of the rights to use the available water will have to be allocated for basic survival needs and domestic food security[35]. Nevertheless, some allocation will have to be made to sustain the existing economic activities such as industries and recreational services and cash crop production, though the percentage share will be much less. The objective is to discourage such economic activities in the regions that the water ecosystem cannot support in the long run. Since

[34] In the Indo Gangetic basin covering UP, Bihar, Haryana and West Bengal

[35] Water for food security can also include, other than that needed for growing food grains, water needed for some of the economic activities that contribute to subsistence.

ecosystem services do not come under the purview of markets (Frederick, 1993), the government will have to invest in procuring that much amount of water from River Basin Organizations as it generates several positive externalities on the society.

The users should pay a "water fee" or "water tax" for obtaining water use rights, and can reflect the cost of resource use, and the cost of environmental degradation caused by the same. In naturally water-scarce regions of India, which also experience high levels of demand for water, both the costs would be high, and higher than that in water-rich areas.

In the urban context, the RBO would allocate water rights to the service providers, which in turn will pay the water tax to the basin authority. The service provider would recover the water charge from the consumers, which will include the water tax, the pollution charges, the operating cost of the agency and its profits.

In water-scarce river basins, enforcement of tradable water rights could promote water markets. With limited access to water in volumetric terms, irrigators would be encouraged to sell their water rights to urban areas as they would be able to pay higher prices for the water. Thereby, farmers could earn greater income than what they could otherwise earn from irrigated crops. Opportunities for such water transfers from rural to urban areas would be greater during years of scarcity. Water transfers that take place from peri-urban areas to Chennai city is an example of informal water markets that emerge during droughts. But, in the absence of well-defined property rights in groundwater, this can create social inequities as only the rich who have the wherewithal would participate in the water transactions and benefit from it (World Bank/GOI, 1998). In Australia, the farmers benefit economically through water trading with scarcity-hit urban areas (Haisman, 2005).

Recognizing and establishing water rights will not ensure the poor community's physical access to water for basic survival needs. The water supply infrastructure is very expensive and it is often not within the reach of the community alone to invest in water production and supply infrastructure, particularly when supply requires transfer of water from long distances. Therefore, it is a pre-requisite that the public utility extends its water supply infrastructure network to places where the poor communities live, and water supply & sewerage connections are provided to them at very affordable costs. The high water and sewerage connection charges could repel the poor households from applying for new connections. An alternative would be to build sufficient number of public stand posts/taps and hand-pumps and public toilets wherever possible. Some municipalities in India like Suryapet in Andhra Pradesh are found to be providing connections at very low charges to BPL families. They have also provided maximum number of public taps and hand pumps for slum dwellers.

### 10.7.8 Legal/Regulatory Frameworks

#### Water Resources and Services

There should be acts that provide the regulatory framework for water resources and water related services like in South Africa. South Africa has the National Water Resources Act, and National Water Services Act. The law that directly relates to water is consolidated into two major acts - the Water Services Act, 1997 and the National Water Act (NWA), 1998. The Water Services Act (WSA) provides the regulatory framework for the provision of water services by local authorities, under the overall authority of the Minister. The NWA mandates the Department to ensure that all activities relating to water resources management, by whomever they are undertaken is in accordance with the requirements of the Act. There are however many other laws which govern activities which are dependent on water, or which affect water resources. These laws are administered by a number of departments in all spheres of Government.

The water services development plan for an urban area will be the principal source of information to responsible catchment/basin management authorities, within which the respective urban centre falls, for the determination of allocations to a municipality or a town Panchayat. The water development plan's requirements must be reflected in the responsible authority's catchment management strategy.

Some of the data in water services development plans will have to be incorporated into the national/regional water resources information systems, and will therefore also contribute to national water resources planning. The plans will also contain details of water demand management and conservation measures, and contingency plans for water-related disasters.

Conversely, when preparing its plan for water-related services, an urban water utility should refer to the relevant catchment management strategy for information about the availability of water to support proposed water services targets; water quality requirements for the wastewater that is to be returned to the water resource after use; and the riparian rights of the downstream water users. Hence, the Acts should provide for administrative/institutional mechanisms for better coordination between resource management agency and agencies that provide water-related services.

In Indian cities, the traditional control of communities over water is systematically being destabilized by allowing urban and industrial interests to compete for the access to water resources and creating conflicts as seen in the case of KUDCEM (Karnataka Urban Infrastructure Development and Coastal Environment Management) Project. In Mangalore city, it causes shortage of water supplies from Nethravathi river during summer months. The Nethravathi river water users association and the other farmers are ordered not to draw water by the City Corporation and the District Administration. The livelihood of thousands of farmers is under threat due to this recent development, and the expansion of water supply lanes under the KUDCEM Project has ignored this sensitive and very important rights issues (Gururaja Budhya, undated).

## Regulatory Framework for Effluent Disposal

The characteristics of the local ecosystem would ultimately determine the degree of pollution of water caused by discharge of effluents of particular quality. Hence, the regulatory framework has to be location-specific, guided by the ecosystem carrying capacity, rather than uniform standard for discharge of effluents[36]. The important aspect of regulation of effluent discharges will be best accomplished with the help of local bodies, as management of ecosystems has to be at the local ecosystem level only--where the dynamic nature of impact of effluents can be appreciated only by those who are affected by it on a daily basis--and cannot be centralized.

The key aspect of protecting environmental resources is the assignment of property rights to facilitate its protection from industrial externality i.e., discharge of waste in the absence of property rights. The rights can be vested with the RBO, which, in turn, can set

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[36] Even before any initiative by the regulators to move towards ecosystem specific standards, cases forced towards such regimes have started merging in India[36]. The case of Tirupur is an example, where faced with widespread damage to agriculture from textile effluents, the judiciary in the face of inaction by the regulators has forced the industry to move on to zero discharge technology, which is even stricter than TMDL which would have allowed some amount of effluent discharge.

norms on effluent quality and exercise the rights by enforcing the effluent standards. The first step is to work out the ecosystem specific standards for effluent discharge.

Since the effluents from industries and urban areas are normally disposed off into surface water bodies, the surface water endowment in a region and the type of aquatic life could be a strong indicator for ecosystem carrying capacity and deciding the effluent discharge norms vis-a-vis water quality. This can be done by the state pollution control board of the local level authority based on inputs from ecologists and environmental hydrologists. But, as a general principle, in surface water abundant areas with perennial streams and rivers, the norm could be less stringent meaning the permissible levels of pollution of water body could be high. In surface water scarce areas, the norms could be stringent.

## Community Regulation of Water Quality through Monitoring

Any regulatory programme will be successful only through effective monitoring. But, we also need to appreciate that fact that with the current density of WQM sites (i.e., 1 in 3780 sq. km area) maintained by the CPCB (source: CPCB, 2008), effective monitoring and regulation is a distant possibility; and achieving that desired level of monitoring by the agency would demand huge amount of additional resources. To achieve this the local council of the areas affected by these effluent discharges can be empowered to collect samples randomly at a frequency based on the toxicity of effluents and shall send it for analysis preferably to a district level accredited laboratory or public funded academic/research institutions-- where sophisticated equipments are already in place--with the local SPCB providing it a supporting technical role. The impact of information availability in the hands of local community is projected to be the key factor in cost effective regulation of pollution in the coming years. The transaction cost of these regulatory exercises will be justified when we compare it against the 10% of GDP India is estimated to be losing due to environmental degradation. The main advantage in involving the local people is that a major portion of manpower cost can be saved, since they will not hesitate volunteering to safeguard their own survival.

Slowly, the local councils can be aided to upgrade their programmes to address domestic sewage treatment, non-point sources of pollution (fertilizer, pesticide run-off from farms) and finally total environmental management for sustainable development. The emphasis should be to utilize existing institutions (academic/research) in every taluka (subdivision of a district) and district. A key institute should be accorded honorary status as a nature node which shall function as the nodal agency responsible for collating technical knowledge regarding best practices in environmental management relevant to their local ecosystem (example--coastal, delta, wetlands, forests, etc.). The key institute need not spend much of its resources for this endeavour as it only needs to collate information available through the web already being actively produced by the ENVIS centres, MoEF, CPCB, SPCBs and numerous institutions around the world.

## Other Important Initiatives for Comprehensive Regulation[37]

Regulation of large industries through economic instruments: For a large industry operating in a rural setting, the economic instrument of coasian bargaining is an effective option. The industry can negotiate with a local council for its discharges and compensations to arrive at a

[37] Some of the ideas presented in this section draws heavily from the article by T. Rajaram and Ashutosh Das titled "Water Pollution by Industrial Effluents in India: Discharge scenarios and case for participatory ecosystem specific regulation," in Futures, 40 (2008): 56-69.

consensus, as it is evolving in the case of Plachimada. The role of the agencies like SPCB/MoEF will be to provide technical assistance to the local council in protecting their interests and to aid the industry in integrated pollution prevention control (IPPC) efforts which are accepted to be a better approach than end-of-pipe treatment technologies. However, such approaches should be resorted to only if pollution control is technically feasible or economically viable. Otherwise, the same industry can be controlled by economic instruments such as pollution taxes, incentives, etc. The immediate steps to implement the above will be to build capacity in local institutions for their effective role.

Regulation of small and medium enterprises (SMEs): The first requirement is to locate them in clusters/industrial estates based on industrial symbiosis and carrying capacity. With most of the SPCBs still clueless regarding the actual number of SMEs, control of these will remain a major socio-economic challenge as they are providers of employment to the vast unskilled labour force in India and have little or no capital to spend on pollution control. The only way out in industrial estates is not only to channel the effluent of SMEs to a CETP, but also to ensure that it functions efficiently. This can be made possible through efficient monitoring, and heavy penalties have to be imposed to compensate the victims. Further, one has to bear in mind that a CETP merely concentrates the contaminants into a solid form i.e., sludge from the clarifiers. The threat of water contamination is fully averted only when this toxic sludge is properly disposed in a secured landfill.

Declaration of critical zones: In areas of heavy ecosystem damage around industrial areas, continuing conflict regarding compensation between the industries unable to afford pollution control measures and communities unable to continue their livelihoods is a no win situation. Areas of heavy damage, where remediation is uneconomical and not possible in the short-term, should be declared as pollution hotspots/critical zones and the affected population must be resettled/ rehabilitated. Let the industries continue and concentrate on economic growth and shall be made to adopt Integrated Pollution Prevention and Control (IPPC) regulation based on long term—5–10 years--binding targets. Where resettlement is not possible, legislation should be framed which will hold the industries responsible to provide livelihood allowance, medical facilities, health insurance and license fees for local resources. A policy to compensate people affected by industrial pollution—and not merely accidental release of hazardous substances as dealt by The Public Liability Insurance Act, 1991 is a significant need.

### Wastewater use

Regulatory frameworks are also needed for wastewater and effluent disposal. The regulatory agency[38] should specify the water quality norms, not only for the treated effluent and sewage from urban areas, but also for the receiving water body and treated wastewater used in agriculture. While complying of the first set of norms would be the responsibility of the industry or municipality, complying of the second would be the responsibility of the river basin organization.

### 10.7.9 Regulatory Framework for Water Resources Management

Regulation is an integral part of the institutional arrangement for water resource management (Mitchell, 1990; Frederiksen, 1998). The regulatory framework needs to have

[38] It is envisaged that the Pollution Control Board would function this role.

two basic components, one for regulating the use of water in quantitative terms and the other for regulating water quality. From the analysis provided in the previous section, it is clear that the nature of regulations for water management has to be location specific, depending on the type of urban area (small or large), the type and sources of water use (whether surface water or local groundwater), the nature of pollution (whether many small polluters, or a few large polluters, etc. The instruments for regulation and the agency for monitoring water use and pollution would also change according to the situation. The regulatory frameworks for WRM in the urban areas for the most common situations are summarized in Table 38.

Table 38: Regulatory Framework for Water Resources Management in Urban Areas for the Most Common Situations

| Type of Water User/ Polluter | Regulation by | Nature of regulation | Instrument for Water Quantity/Quality Management | Vol. Allocation/ Water Quality Monitoring by | Water Metering/ Water Quality Testing |
|---|---|---|---|---|---|
| **Water Resources Management** | | | | | |
| Water utility using surface water for municipal supplies | River Basin Organization (RBO) | Evolving broad WRM plans for the basin, and defining water rights for different sectors | Volumetric, basin-wide allocation; enforcement of water rights; and levying water tax from the utility | RBO | Metering of water withdrawal by the utility |
| Urban water utility using local groundwater | RBO | Do | Do | RBO | Do |
| Groundwater pumping by individual urban consumers* | No regulation | | Groundwater tax (based on wells kept at a very low level | | No metering of withdrawals, but only the no. of wells |
| **Water Quality Management** | | | | | |
| Large cities located within large river basins | RBO | Setting norms on effluent quality | Pollution charges; payment for WWT to the service provider; and performance monitoring | State Pollution Control Board (SPCB) | SPCB |
| Small towns located within large basins | Do | Setting norms on effluent quality | Pollution charges and payment for WWT system; and performance monitoring by community | By community with technical support from SPCB | Accredited district level agencies of the state government or academic institutions |
| Small towns located outside large basins | Local community | Setting norms on effluent disposal based on knowledge of the | Use of environmental protection laws, with technical | By community with technical support from SPCB | Do |

| | | | | | |
|---|---|---|---|---|---|
| | | local eco-system | support of SPCB | | |
| Regulation of large industries | RBO | Setting norms on effluent quality, including that for quality of different types of pollutants | Direct regulation and technical assistance | Pollution control board | Pollution control board |
| Large number of small industries | RBO | Placing them all in one locality and levying pollution tax | Investment in CEPTs | Pollution control board | State Pollution Control Board |
| Declaration of critical zones | RBO | IPCC with 5-10 year binding targets | Resettlement, or livelihood allowance + medical allowance | | |

Source: based on authors' own analysis

* In situations of abundance of groundwater in the locality

## 11.0 WATER SUPPLY AND SANITATION PROVISION IN POOR URBAN NEIGHBOURHOODS

Many constraints have hindered the efforts of the various institutions to provide adequate water supply and sanitation. They include: firstly, institutional inadequacy and insufficiency of conventional approaches which hindered participation of stakeholders and informal institutions in infrastructure provision and management (Stren, 1989; Fekade, 1997; UNCHS, 1996; Arrossi *et al.*, 1994; Kyessi, 2005). Secondly, supply driven infrastructure provision sticking to rigid planning/design standards and regulations thus failing to bridge the growing gap in services especially for low-income communities.

For instance, sticking to a rigid supply norm of 135 or 100 lpcd of water for all urban populations (depending on size of the city/town) can reduce the ability of the utilities to benefit the entire population, when water is scarce or when the terrain conditions are difficult or when the communities live in fringes. Similarly, trying to provide access of the urban poor to a centralized sewerage system would be difficult as the poor communities live in low lying areas or river beds which are often drainage outlets of urban storm water. Also, the fact that many low income communities live in illegal settlements automatically deny them rights to infrastructure provisions such as piped water supply, drainage or sewerage connection, as they lack proper entitlements.

Thirdly, high cost of conventional systems that did not recognise progressive improvement of infrastructure (Choguill, 1996; Choguill, 1999). The progressive improvement model may seem to favour the majority of households in developing countries that has less than US$500 per year ((Aligula, 1999) and spends more than 50 per cent of that on food (Kironde, 1999; Kyessi, 2005). The approach for water & sanitation hence has to be demand driven, flexible vis-à-vis infrastructure provisions, with dependence on informal institutions.

An experience of demand driven community-based urban water supply model is from the two fringe areas if Daar e Salaam. The entire community-based work was mobilized by the *Mtaa*, or the sub-ward committee, the lowest unit in the administrative/political hierarchy. To enable Mtaa leaders discharge their duties and functions without depending too much on technical and financial assistance from the upper central organs, and at the same time coordinate provision of basic community services such as potable water, a better working institutional structure was required. Mtaa had put in place administrative structures to work with the sub-ward leaders, in the form of several sub-committees. They are Executive Committee; water management committee; etc. These sub-committees work very closely with the Ten Cell Leaders.

The technical, natural, human and financial resources were mobilized from the neighbouring local government bodies, donors, civil society members, private individuals and politicians. Three types of models exist for water supply:

1. Privately managed and operated water system:

2. Community-based water management system

3. Household water management system

This might be essential to meet the needs of people belonging to different income groups (Anzerona et al., 1998).

Table 39: Water supply for urban fringes: gradual improvement model

| Time horizon | Step by step technological change | | | Remarks |
|---|---|---|---|---|
| stages | Stage I | Stage II | Stage III | |
| Type | Traditional well | ▪ Shallow hand pump | Motor pump and raised tank with stand pipe and with distribution network | Technical support from the municipality/ corporation needed for design of the well, pump set, storage and distribution system |
| Scale | Small and open; use bucket to scoop water | ▪ Medium scale (sufficient for 40-50 families) | Large scale up to 4-5,00 cubic metres (sufficient for up to 1,000 families | Large and consolidated slums, with many adults having voting rights; ration cards |
| Operation and maintenance | Household member | ▪ Household members<br>▪ Hired attendant | ▪ Household members<br>▪ Hired pump operator | When the scale increases, community members won't be able to provide O & M |
| Quality of water | Biologically contaminated | | Chemical quality may not be assured; but chances of biological contamination are less | Periodic water quality testing might become necessary |

Source: based on authors' own analysis

Table 40: Water supply for slums: gradual improvement model

| Time horizon stages | Step by step technological change | | | | Remarks |
|---|---|---|---|---|---|
| | Stage I | Stage II | Stage III | Stage IV | |
| Type | Stand posts | ▪ Surface Storage Tank with several taps | ▪ Storage & pumping system with distribution pipes to each house<br>▪ Obtaining land tenure is crucial | ▪ Individual households connected to the municipal sewerage system<br>▪ Obtaining land tenure is crucial | Technical support from the utility needed for planning & design of storage and distribution system; sewerage connection<br><br>The real owner is willing to transfer the ownership rights to the slum dwellers on payment of compensation or without |
| Scale | Cover a few households in small slums | ▪ Medium scale (sufficient for 40-50 families) | Large scale up to 4-5,00 cubic metres (sufficient for up to 1,000 families | Large slum with 4-500 households; per capita water use comes up to the "norm" | Stage III & IV for large & consolidated slums, with many adults having voting rights; ration cards |
| Operation & maintenance | No special O & M work | ▪ Slum Committee responsible for protection of taps, and ensure distribution of water | ▪ Slum committee to take O & M decisions; recover water charges<br>▪ Hired pump operator for routine operation<br>▪ Plumper hired locally for repairs | ▪ Slum committee to take O & M decisions; recover water charges; collect connection charges for sewer;<br>▪ Hired pump operator for routine operation<br>▪ Plumper hired locally for repairs | When the scale increases, community members won't be able to provide O & M |

Source: based on authors' own analysis

## 11.2 Service Delivery Models for Poor Urban Consumers

Direct subsidies are an increasingly popular means of making infrastructure services more affordable to the poor. In order to make urban water affordable to the poor, under the direct subsidy approach, governments pay part of the water bill of poor households that meet certain eligibility criteria[39]. This is an alternative to direct provision of subsidy to the utility, which would create disincentive for them to perform, as the community members have to pay very little for obtaining water services.

Simulation techniques can be used to inform the design of direct subsidy schemes ensuring that they are both cost-effective and accurate in reaching the target population (Howard and Pond, 2002).

The biggest challenge in provision of direct subsidies is in reaching the benefits of subsidy to the poor alone, and in reducing "the errors of inclusion". "Zoning method" is found to increase the errors of inclusion, wherein a large percentage of those who benefit from subsidies are non-poor. Since it is difficult to assess the income levels of the households accurately and decide on the eligible households for subsidies, proxy methods have to be employed using certain criteria. Simulation technique can be employed to determine a combination of criteria which best match with the condition of poor households, which are likely to be found least in non-poor households. What is important is to make sure that the subsidies are not available for higher levels of use, which can create disincentive for efficient use.

Provision of direct subsidies for domestic water services, combined with volumetric water rights, with water for basic survival needs made free[40], as introduced in South Africa under its new water law, would increase poor people's ability to access water thereby improving equity. The Urban Water management council will have to be responsible for enforcing water rights, which would mean monitoring water use by different segments of urban community.

But, what is also equally important for the poor people to enjoy their basic rights to water for survival, hygiene and environmental sanitation, is to have a good physical infrastructure for water supply & sanitation including proper piped water supply & individual tap connections, supported by institutions at the local level which monitors the service delivery. Concepts like "slum networking", tried and succeeded in Ahmedabad, Indore and Bhopal could be up-scaled for poor communities in urban areas to benefit from the services.

One method is to provide connections for BPL families at very highly subsidized rates. Such practice was found in Suryapet Municipality in Andhra Pradesh, which has won the award for best practices under ISO 14001. While the municipal council charges Rs. 5000 from ordinary consumers for new connections, it charges only Rs. 200 from BPL families.

## 12.0 FINANCING URBAN WATER SECTOR

An increasing realization of the limitation of public resources in relation to the estimated investment requirements suggests the need to enhance the resources for the sector (World Bank/GOI, 1998).The general belief is that new investments in the water sector alone are important. It is also important to sustain the returns from the earlier investments,

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39 This approach was first used in water sector reforms in Chile in the early 1990s and is an alternative to the traditional method in which governments pay subsidies directly to utilities often allowing the price of water to fall below economic costs indiscriminately.

40 Here we refer to only "water fee" or "water tax", and not the cost of production & supply of water.

through continued investments for their upkeep. To achieve the MDGs (of reducing the proportion of people without access to safe water & sanitation, an additional 1.5 billion people have to be covered in provision of safe water supplies; and 2 billion people to be covered in sanitation

Water sector investments have two divisions: water resource sector investments; and investments in the service sector. Dam /diversion system building is part of water resource sector investments, and forms part of water resource development. Watershed management can be put under resource management. Water supply systems, sanitation infrastructure, sewerage and waste water treatment systems can be under services sector.

## 12.1 Issues Affecting Financing of Water Sector by Lenders/ Investors

The most important issue concerning the financing of urban water sector is governance. They include: lack of legal framework, and effective regulators; political interference; resistance to full cost tariff; lack of transparency in issuing contracts. For instance, they are no laws which protect the interests of both investors and consumers when it comes to investments in water infrastructure.

There is often a lot of political opposition against price hike, cutting connections for non-payment of service charges, taking action against illegal users, including imposition of penalty, including large cities like Delhi. The only exceptions are states which have high levels of literacy such as Kerala. Also, users and opposition political parties, in an attempt to patronize them, resist full-cost tariffs, as people generally perceive drinking water supply as a public good. Also, lack of transparency maintained by public utilities in issuing contracts for undertaking various physical works is one reason why international institutions shy away from putting in their resources. The kick backs involved in issuing of work contracts hampers the financial viability of schemes.

One common problem found in many small town municipal councils and municipalities is the poor management structure. The urban engineers are under the administrative supervision of the chairman of the municipal council, which is an elected body. But, their technical superiors are with the state water supply & sewerage boards functioning at the state level. As a result of this, they often have to undertake things which fulfil the interests of their political bosses, compromising on what is technically and economically more efficient.

Often in many developing economies like India, the social, economic and environmental interest conflict with each other. For instance, sustainable water supply solutions for some of the water-scarce regions require large-scale water transfer schemes, which can cause huge environmental effects. The urban users are often not willing to cover the environmental costs of degradation of water resources, one problem being the affordability of water. But, recovering these costs is crucial to compensate for the social and environmental effects of such developments. Same is the case with building environmental management systems. Treating sewage, which is part of improving the environmental services, requires huge investments. But, water supply becomes unaffordable for most consumers if they have to pay the sewerage fee as well. On the other hand, the state does not have financial resources to support public investments for wastewater treatment systems.

Under-paid and ad hoc technical staff members of municipalities have least incentive to learn and execute their work. On the other hand, the municipality is never able to build a core team of experienced staff. In the absence of competent technical team, which is capable of executing the work and running of the systems, it is difficult to convince financing institutions to provide loans for large infrastructure projects.

In addition to the specific issues discussed above, there are some generic issues concerning financing of water utilities. They are applicable to most water utilities. They are: very long payback period, and very low rate of returns; very high capital investments; political pressure on awarding of contracts; sub-sovereign risks: responsibility with local governments that lack financial powers; foreign exchange risks; and projects of long duration entered into with poor initial information--particularly lack of information on hydrological and demographic variables.

## 12.2 Improving the Aid Possibilities

- Linking aid to outputs: using aid for subsidizing water bills of poor consumers; release of aid funds on the basis of number of new connections provided; or quality of treated wastewater or environmental flow quality; or time bound subsidies to consumers on transition to full-cost tariffs

- Create an agency for monitoring the performance of water utilities on the basis of feedback on the quality of construction of water supply and sewerage infrastructure; and WSS services received from the consumers. This agency can interact with a Citizen Oversight Committee, which will be mandated to perform these tasks.

- The need for new contract laws and best practices in preparing legal agreements to work out better contractual agreements between public and private agencies in executing contracts

- To improve the financial sustainability of water utilities: payment of water tariff to the service provider rather than the government as part of the overall tax payment. This can create among agency officials incentive to improve the recovery rates. Formation of new water boards, which are independent of the Municipal Corporation or Municipality, might help.

## 12.3 Strengthening Financial System and Improving the Financial Viability

Increasing the external aid is one of the strategies for making many new projects financially feasible. This would contribute to improving the overall financial sustainability of urban water utilities in the long run, as timely investments in expanding or improving water supply infrastructure or retrofitting would help avert complete collapse of the system, thereby stretching its life. As costs can significantly come down on annual basis, this would improve the financial working of the utility.

Along with this, the financial system needs to be strengthened through increasing its market orientation, and financial viability needs to be improved through efficiency improvements and rational tariff structure

### 12.3.1 Strengthening the Financial System

One approach is to attract private sector finance through private sector participation. The other approach is tapping capital markets (bonds) and creation of market intermediaries. The municipal bodies, which are able to restructure their revenue account finances, should be encouraged to borrow money from the market, subject to credit ratings by appropriate agencies. But, there are sectoral and institutional constraints to borrowing: 1] lack of financial viability in the sector and inadequate capacity to absorb funds efficiently; 2] inadequate and inappropriate accounting and auditing practices among the UWSS providers which make transparency and market disclosures difficult; 3] excessive dependence of local authorities on the state government; 4] lack of a well-developed bond market which limits the available financial products; 5] lack of any sustainable credit enhancement or insurance opportunities; and 6] lack of familiarity of the financial sector with urban sector institutions.

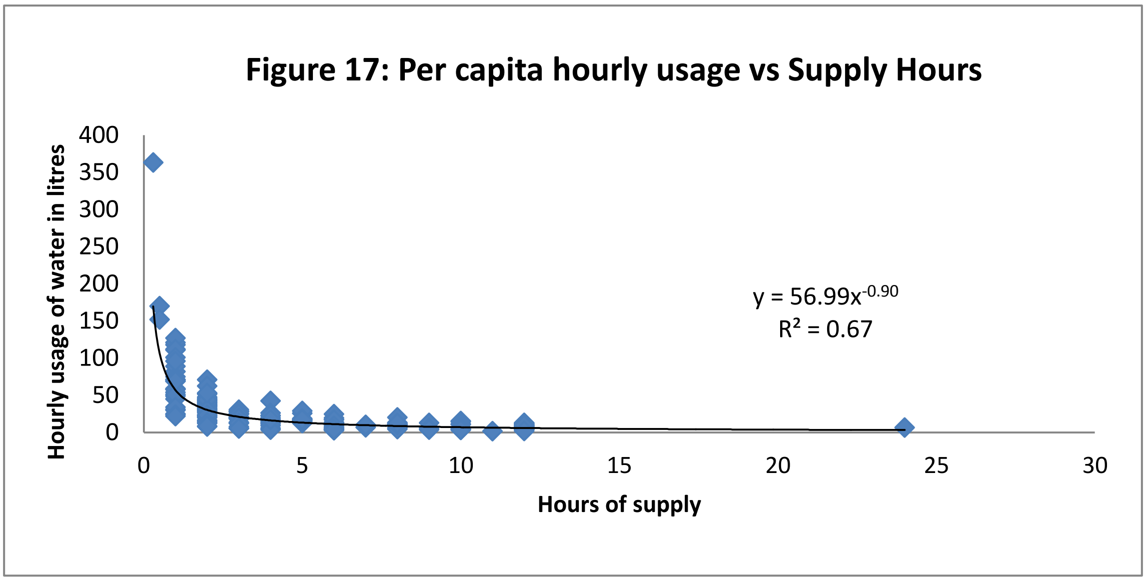
### 12.3.2 Improving Financial Viability

While improving the financial viability would contribute towards improving the financial sustainability of the utility, it would also increase the ability of the utility to tap funds from the market. The various measures for efficiency improvements (physical and managerial) are discussed below. The tariff reforms, including the norms and criteria for changing tariff structure, are discussed in one of the previous sections.

#### Improving Financial Working: 24 x 7 Water Supply and Metering

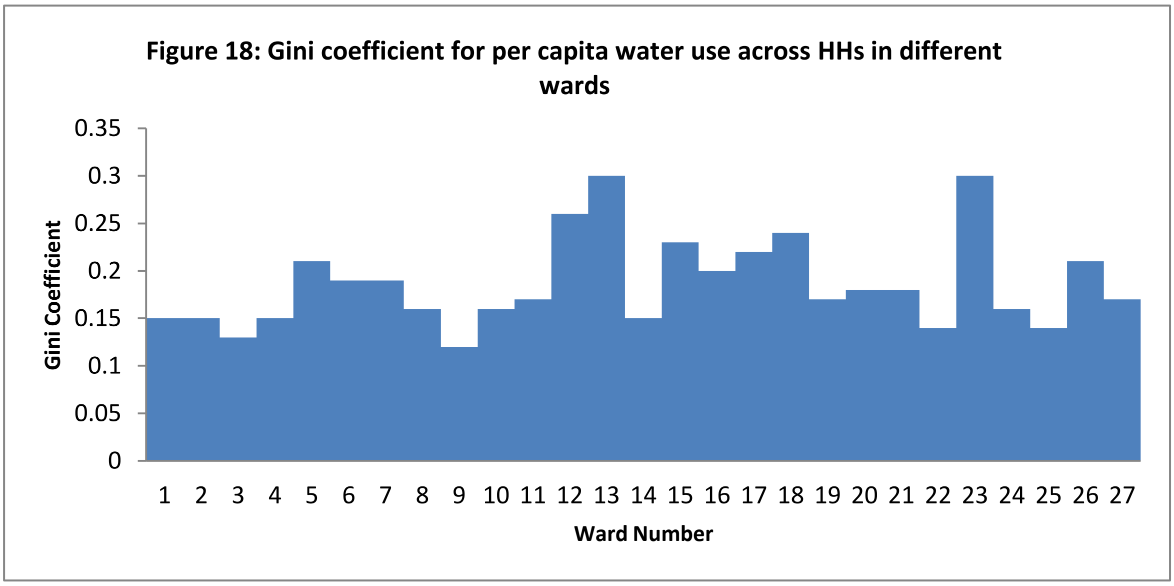
Before we look at the merits of 24 x 7 water supply, we would examine the effects of intermittent water supply. Indian cities and towns have intermittent water supply. In fact there is hardly any city or town in India which has 24 x 7 water supply adopted for the entire jurisdiction (ADB, 2007). In urban areas, as water becomes more and more scarce, utilities tend to resort to restricting the duration of water supply. For instance, in Rajkot city, water is supplied to consumers only for 20 minutes a day. This is based on the assumption that reducing the duration would result in reduced consumption. But, this is not true, as evident from the chart below generated on the basis of data from around 301 towns/cities in India. In fact, the average per capita consumption is higher in cities which supply water for limited hours. The relationship between duration of water supply and the per capita hourly water use was "inverse-exponential", or in other words, increase in duration of water supply resulted in disproportionate reduction in average per capita water use (Figure 17). There are exceptions to this. For example, in the city of Chennai, the actual average water consumption (32 litres per capita per day) was extremely low, while the duration of supply was also very low (1.5 hours per day). This resulted from acute physical shortage of water, which led to many areas going out of the service of the metro water board.

In addition, it creates huge problems of inequity in access to water. Certain sections of the population would be completely left out of the service. Amongst those who get water, by virtue of their position in the hydraulic system, the poor consumers will have the least ability in fetching water. The rich urban consumers would be able to manage their supply requirements by putting up large storage systems. This was found in a small town named Mulbagal in Karnataka where the per capita use consumption was found to be a direct function of the per capita intermediate storage capacity, and the same was a function of the household income.



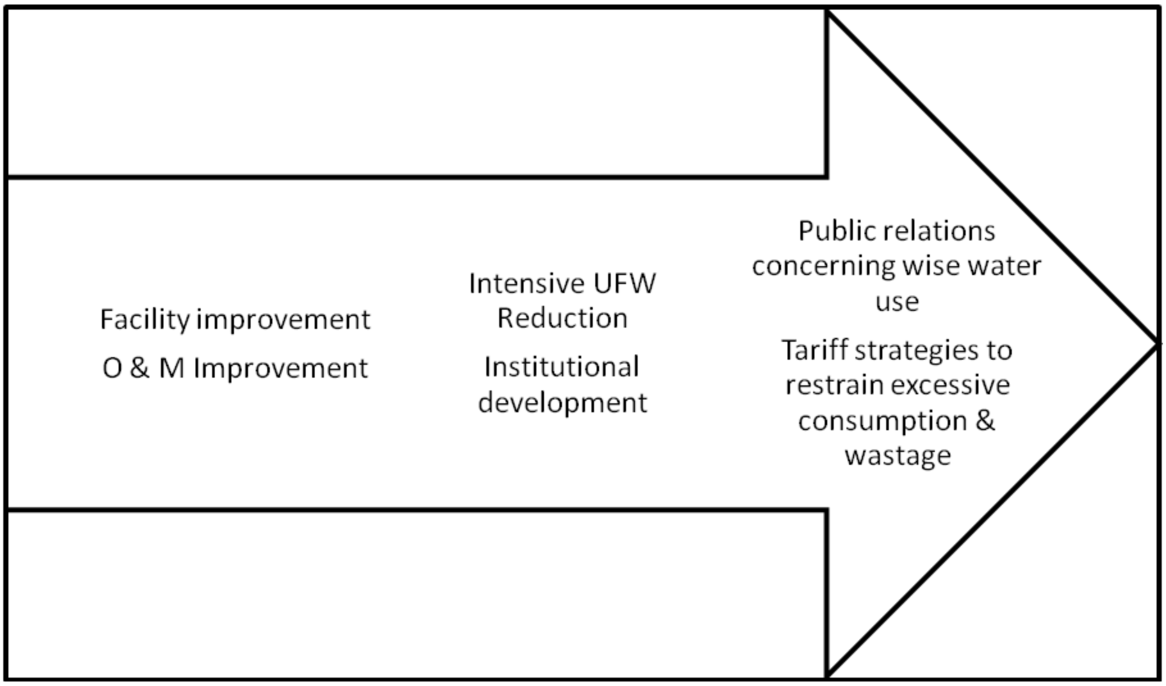

The inequity in access to water was also high (Gini coefficient = 0.3). Further, it was found that the inequity was of slightly higher degree in wards, which had lower average per capita water storage (Figure 18).

Intermittent water supply comes with a huge cost. While intermittent supply reduces the ability of the water utility to raise the water tariff and charge the full cost, owing to poor quality of water supply, it comes with a heavy cost to the consumers. They actually start incurring a very high cost to "cope with" the poor quality water supply (Source: David Foster, per. Communication). A 2005 survey done in Delhi showed that while the consumers pay a very small amount as monthly water bill, the actual coping cost of adjusting to 4-hour water supply is very high. Both added together becomes much higher than the actual amount they are willing to pay. In the case of under-served communities (un-authorized slums), the coping cost was close to the affordable water bill (Rs. 210 per month) (Misra and Chuan Eng, 2007). This essentially justifies the need for improving water supplies for the poor




communities, who live in the un-authorized slums.

If 24 x 7 water supply system is to be introduced in a water supply system, the pre-requisite is to minimize the UFW, including prevention of theft of water and reduction of leakage. Metering would enable detection of illegal tapping of water, one part of the UFW. Metering would enable introduction of volumetric pricing also. This will impact on the water consumption at the end use level also. The 24 x 7 water supply would reduce the need for providing intermediate storage systems also. The steps involved in moving from intermittent supply to 24 x 7, water supply (adapted from Wachasundar, 2007) are given in the diagram below.




The benefits of reducing unaccounted for water are of three types. First comes from the cost saving resulting from the reduction in amount of non-revenue water supplied. This is the impact of metering, which enables the utility to find out how much water is loft in theft, thereby able to detect the illegal connections and regularize them. The second saving comes from the reduced wastage at the user level which is the impact of volumetric pricing. The third comes from the saving in the cost of provision of intermediate storage systems.

The cost saving can be mathematically expressed as:

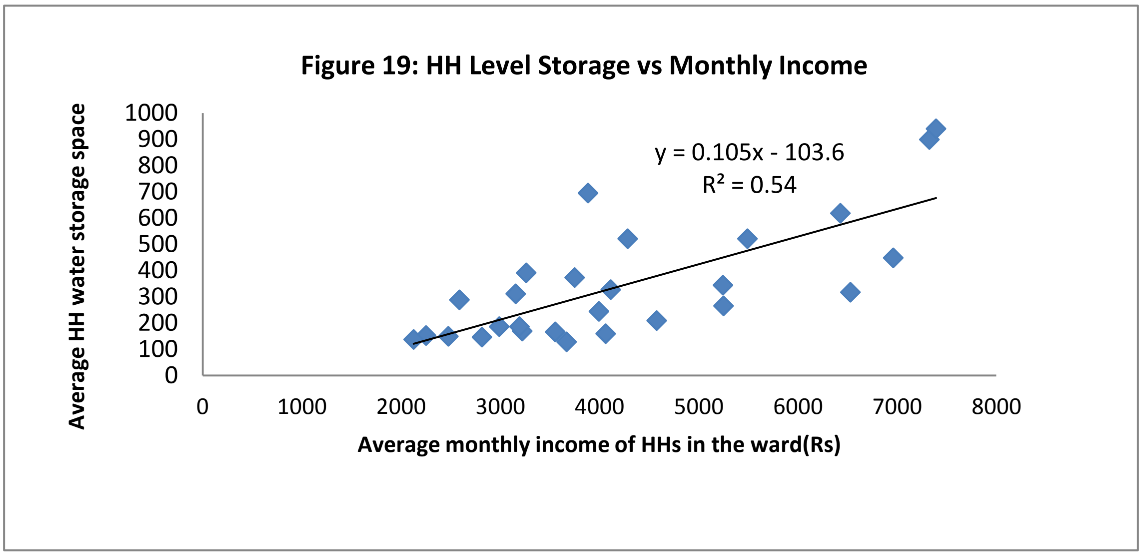
$$C_{saving=} \frac{X_1\,[(A_1 - A_2)C_{water-supply} + \emptyset * C_{storage}\,]}{(1 - A_2)}$$

Here, $X_1$ is the initial water supply at source; $A_1$ and $A_2$ are the UFW in fractions; $\emptyset$ is the total storage capacity available as a fraction of the total annual volume of water supplied by the utility; and $C_{storage}$ is the average cost of storing water per unit volume. This can be estimated by taking the weighted average of the capacity (volume) of the storage facilities maintained by housing stocks belonging to different segments of the society. In one of the towns, named Mulbagal in Karnataka, it was found that the per capita domestic storage is a function of the income (see Figure 19). Hence, by covering different socio-economic strata in the survey would help obtain realistic figures of the storage facilities available for water in the service area of the utility. Therefore, it is also obvious that poorer the quality (in term of reliability and duration) of water supply, higher would be the cost of providing intermediate storage. Consequently, higher would be the cost saving due to 24 x 7 water supply. The cost saving can also include the cost of depleting the resource, which is lost in distribution systems and theft.

In case such storage facilities are not available, the opportunity cost of intermittent water supplies would be high as households will have to adjust their routine to match the water supply schedule. However, evaluating this cost is complex as they depend on the socio-economic profile of the household members. So, here we have considered only the situation where family invests in intermediate storage systems.

Since we assume that the final UFW is the same, the cost saving (benefit) would depend on what was the initial level of leakage in the system. Now, the economic dynamic of reducing UFW with metering improves with the extent of unaccounted for water in the system before rehabilitation and the cost of production & supply of water; the original volume of water supplied; and the cost of rehabilitation.

While the cost of rehabilitation is also a function of the degree of reduction in leakage along with that of other interventions like meter installation, at high levels of leakage, low degree of reduction in the leakage could be achieved with minimum costs (Montgomery Watson, 2000), and for higher degrees of reduction in leakage, the cost would go up exponentially. Hence, what is most important from the point of view of cost is the level at which the leakage is maintained, rather than the degree of reduction.




Here, the unit cost of rehabilitation (involving introduction of new service lines, leakage prevention and installation of meters etc.), corresponding to reduction of pipeline leakage to a certain level, would again be an inverse function of the area covered. This is because of the fact that when same volume of water is supplied to a small area, the amount of engineering infrastructure required to do leak proofing, number of meters required to measure the supplies and the length of service lines required would be less.

This means that for the same size of population, the economics of 24 x 7 water supply would improve under the following conditions: 1} the population density is very high, meaning the same amount of water would be supplied over a smaller area, reducing the cost of the infrastructure; 2] the cost of production & supply of unit volume of water is relatively high; 3] UFW before intervention is very high; and 4] quality of water supply prior to introduction of 24 x 7 is very poor in terms of reliability and duration.

## Impact of 24 x 7 Water Supply Project in Nagpur, Maharashtra

Nagpur city had decided to introduce 24 x 7 water supply with leakage reduction, installation of new service connections and metering in the city in a phased manner. The calculations of the investments required per category gives the results, which are presented in Table 41.

Table 41: Category-wise HSC Investment costs (MRs)

| Sr. No | Category of HSC | Total HSC | Investment Cost (Lac) | Investment Cost per HSC |
|---|---|---|---|---|
| 1 | Slums | 4920 | 182 | 3703 |
| 2 | Outside Slums | 11092 | 1845 | 16636 |
| | | 16112 | | |

The cost-benefit analysis has shown that the proposed investment is financially viable since the pay-back period is around 5.5 years on the basis of 18MLD of water saved at the official NMC rate of 5,54 Rs/$m^3$ (FY2006-07).

The implementation of the rehabilitation plan was started in April 2008 and was to last for 15 months. The various activities of the rehabilitation plan (HSC replacement, metering, pipes replacement and implementation of the billing application) was to be carried out in parallel in order to optimize time.

About 15,000 connections, including 100 slum connections were converted into 24x7 water supply system (Source: Chari, undated; Rathi, undated). The project benefits to Bajiprabhu DMA of 144 regular connection and 150 slum units are as follows. The water supply hours increased from four and a half to 24. The water consumption was 440$m^3$/day for a Bajiprabhu Nagar with 4.30 hrs has increased to 504$m^3$/day after 24 hrs supply of water. Before conversion the average pressure at consumer water taps was 2-5 meters and now it reaches to 10-12 m. It resulted in to energy saving for consumers as water reaches directly to overhead water tank. The continuous pressurized network has avoided the contamination of water from leaking House service connections which were replaced under this project (Rathi, undated).

As Table 42 shows, the average UFW was 69% in the zone during base line study, and was reduced to 33% in DMA of 144 regular connection and about of 150 slum dweller in Bajiprabhu Nagar DMA (Source: Rathi, undated). The UFW would reduce further after completion of slum connection rehabilitation. Total billing volume has been increased from 137 $m^3$/day to 338$m^3$/day (286$m^3$/day to regular consumer and 52$m^3$/day to slum consumer against zero billing slums earlier).

Table 42: Water Supply and Use Scenario under UFW Reduction Project, Nagpur, Maharashtra

| Total Volume of Water Supplied X | UFW | Accounted for Water ($m^3$/day) | UFW | Water saving | Economic cost saving (Rs/annum) |
|---|---|---|---|---|---|
| | A | B | C | D | $\left(X_1 - \left({}^{B_1}/_{B_2}\right) * X_2\right) * C_{supply}$ |
| 440 | 69% | 136.40 | 303.60 | | |
| 504 | 33% | 337.00 | 167.00 | 136.60 | |

The total cost of doing this (metering, 24 hour water supply, and providing new HSC) for 144 urban consumers plus 150 slum dwellers was estimated to be Rs. 2765,884 (Rs. 370300 +Rs. 2395584). The annual cost saving is Rs. 465170 (236*365*Rs.5.4/$m^3$). Even if we assume that the rehabilitated system has a life of 12 years, the full cost would be recovered. An alternative to evaluate the economics of UFW reduction is to look at the cost of effectively increasing the water supplies through UFW reduction against the actual cost of production & supply of water. This works out to be Rs. 2.67/$m^3$ of water against the prevailing cost of production of Rs. 5.5/$m^3$ of water. The effective increase in water supplies over a 12-year period is estimated to be 1.033 MCM with an additional investment of Rs.2.765 million.

## 13.0 POSSIBLE EFFECTS OF DISASTERS ON WATER AND SANITATION SYSTEMS

Table 43: Disasters, Possible Damages and Disaster Prone Regions in India

| Disaster and Component | Possible Damage | Vulnerable Regions |
|---|---|---|
| **Earthquake** | | |
| Water sources | Landslides; sediment load in reservoirs; dams developing cracks; structural damage to aquifers and wells | Earthquake prone areas of India (Sub-Himalayan region of Kashmir & NE); Kachchh; Mumbai islands |
| Heavy structures | Structural damage to sedimentation tanks due to differential settling; structural damage to large OHTs | |
| Pumping stations | Electrical system damage; damage to machinery | |
| Pipelines for drinking water & sewage | Deformation of pipes; cracks in joints; joint failures | |
| **Landslides** | | |
| Water sources | Increased sediment load in reservoirs; increased channel sedimentation and damning; mudslides destroying intakes in river beds | Cities/towns located in western Ghat region, and Sub-Himalayan region of Kashmir and NE |
| Pipes (drinking water & sewage) | Deformation or breaking of pipes which can increase landslide damage | |
| **Floods** | | |
| Water sources | River changing course; high sediment load in river water; contamination of groundwater with biological matter & bacteriological contamination | Cities located in the flood-prone areas of Ganges/Brahmaputra river system, Narmada valley and Tapi river |
| Water treatment systems | Overflow of sewage and its spill into natural water bodies | |
| Pipes | Deformation/breakage of pipes; damage to pipeline erection structures | |
| **Cyclones** | | |

| | | |
|---|---|---|
| Water sources | Damage to small water impounding structures due to the flash flood that occur due to heavy downpour | Cities located in coastal Saurashtra, coastal Andhra, and coastal Orissa and Tamil Nadu |
| Heavy structures | Structural damage to overhead tanks, pipeline erection structures in cyclonic winds | |
| Pipes | Cracks in pipeline joints | |

Source: adapted from UNDP/DHA (1994)

**Integrated disaster management for water supply & sanitation**: the various aspects of integrated disaster management are: risk identification and assessment; risk mitigation measures; risk transfer; risk preparation; emergency response and rehabilitation. The disaster can be human induced or natural. The risk assessment would include: risk identification (identifying whether any type of risk exists); risk analysis (frequency of occurrence, magnitude); evaluation of vulnerability (population threatened); risk evaluation (threat and vulnerability); and monitoring of natural occurrences and forecasting of disaster.

The risk mitigation measures could be those which reduce the death toll or those which reduce the economic losses. The risk mitigation measures could be structural and non-structural; and would include territorial disposition and construction & maintenance codes; provision of economic incentives for promoting mitigation measures. The risk transfer could include: insurance against disaster induced losses; use of financial market instruments; and privatization and concessions. The risk preparedness would include early warnings about floods, droughts, earthquakes and landslides.

There are five different types of measures available for use in planning disaster mitigation programs: 1] Engineering and construction measures; 2] Physical planning measures; 3] Economic measures; 4] Management and institutional measures; 5] Societal measures.

## 13.1 Mitigation Strategies for Water and Sanitation Impacts

### 13.1.1 Earthquakes

**Mitigation:** Avoiding siting of high dams in seismically highly active zones; seismic design for dams; design of engineering structures for water supply such as pumping machinery and overhead tanks has to be made to withstand vibration forces; pipeline joints to withstand sheer forces caused by heavy ground settlements; enforcement of compliance with building code requirements and encouragement of higher standards of construction quality.

**Community participation:** Community's willingness to construct earthquake-resistant buildings; their desire to live in houses that are safe from seismic forces; and high level of awareness about earthquake-related risks; community's knowledge of what to do in the event of an earthquake occurrence; participation in earthquake drills, practices, public awareness programs. Community action groups for civil protection: pipeline repairs, electric machinery repairs etc.

### 13.1.2 Food Control

**Mitigation measures**: Design of reservoir spillways for discharging flood flows that occur once in 100 years, land-use control and locations planning to avoid potential flood plain being the site of vulnerable elements such as open wells used as water source, and on-site sanitation systems like leach pits, wastewater treatment systems. Design of engineering structures built in floodplain (pipelines, pipeline erection structures) has to withstand flood forces and design for elevated floor levels, seepage-resistant infrastructure.

**Community participation:** Sedimentation clearance, dike construction, awareness of flood plains and flood prone areas. Houses constructed to be flood resistant (water-resistant materials, strong foundations). Living practices reflect awareness: storage and sleeping areas high off ground. Flood evacuation preparedness, boats and rescue equipment.

### 13.1.3 Land Slides

**Main mitigation strategies:** Location planning to avoid hazardous areas being used for settlements or as sites for laying down pipelines, structural design to withstand or accommodate potential ground movement, pile foundations to protect against liquefaction.

**Community participation:** Community members recognizing land instability potential and identifying active landslides, construction of strong foundations for structures, compaction of ground locally; their willingness to undertake slope stabilization through terracing and forests, and rock-fall barriers (trees and earth banking).

### 13.1.4 Cyclones

**Mitigation strategies**: Design of heavy water infrastructure such as large overhead water tanks, and high pipeline erection structures in coastal towns falling in cyclone-prone areas should be done to withstand the load of high and strong wind forces; planting of wind breaks in coastal areas; design of water impounding structures should be made to withstand the flash flood; and provision of wind safety buildings for community shelter in vulnerable settlements.

**Community participation:** Construction of wind-resistant or easily rebuilt houses, securing fixing of elements that could blow away and cause damage or injury elsewhere, e.g. metal sheeting, fences, signs; preparedness for storm action; taking shelter in strong, wind-resistant buildings; protection measures for boats, building contents or other possessions at risk.

## 14.0 INVESTMENTS IN URBAN WATER INFRASTRUCTURE

This can be divided into: investments for building new infrastructure; investments for operation and maintenance of the existing infrastructure for their better upkeep. Depending on the type of infrastructure, the investments can be classified into those for: water supply; sanitation and sewerage disposal; storm water collection and disposal (drainage system); wastewater treatment system; and solid water collection and safe disposal.

## 14.1 Water Production and Supply

We have earlier seen that the water supply cost, which includes the cost of production and supply of water per unit population, is a function of several factors, such as population density, technology/method employed for obtaining, treating & supplying water, and the water quality standards followed. The last factor in a way would decide on the method employed for obtaining and treating water. Stringent water quality standards would mean use of sophisticated treatment systems to treat the raw water to higher quality or going for alternative sources of water supply[41]. Further, the technology employed for water supply is also a function of the water resource endowment in the locality under consideration. In water scarce regions, the distance to original source of water is very high, which increases the cost of production & supply.

Nevertheless, it is clear that the single most important factor that would determine the investment requirements for water supply is the water resource endowment of the region under consideration. So, water-scarce regions should have different cost norms as compared to water-rich regions. Hence, for estimating the size of investment, two typologies of urban areas are first made. Now, it is also known that the size of investment required per unit of population is a function of the supply norm vis-à-vis the per capita water supply per day. Larger cities need to be supplied larger quantum of water for every unit of population. This is to accommodate for the water for environmental services (like tree plantation) and supplying water for hotels, gardens, industrial estates etc, and not for flushing of sewage. In fact, it is expected that under IUWM, all cities and towns will have the same per capita water supply norm for domestic water supply. Hence, the cost per unit of population would be higher for larger cities. Therefore, in order to avoid the discrepancies in cost estimation, the costs are provided per unit volume of water rather than for unit population.

This, however, does not include the resource cost, but the cost of laying down the pipelines for water conveyance from the source, installing pumping devices, setting up raw water treatment plants, and water distribution and delivery system in the urban area. The cost of water supply for surface water based schemes and groundwater based schemes in Class I and Class II cities under different typologies are given in Table 44 and 45, respectively. From the total additional water demand to be met (see the demand function) and the unit cost of water supply, the cost of production and supply of water can be obtained.

Table 44: Average **c**ost of production per-cub-meter of water supply in Class -I cities

| **Typology** | **Average cost of production per cubic metre** **Class-I cities** | |
|---|---|---|
| | **Surface water** | **Ground water** |
| 1 | 3.79 | 2.03 |
| 2 | 1.37 | 0.87 |
| 3 | 0.96 | 0.87 |
| 4 | - | 0.46 |
| 5 | 3.67 | - |
| 6 | 1.73 | 2.67 |
| 7 | 1.72 | - |

41 In many semi arid and arid regions, increase in salinity of local groundwater forces municipalities to look for surface water sources for water supply. The reason is that treating the local groundwater is not only economically viable, but also technically not feasible. This eventually increases the cost of water supply, as water has to be imported from long distances.

| | | |
|---|---|---|
| 8 | 4.95 | - |
| 9 | 2.00 | 3.50 |
| 10 | 0.74 | 1.67 |
| 11 | 2.25 | 1.06 |
| 12 | 2.78 | 0.85 |
| 13 | 2.24 | 2.07 |
| 14 | 1.74 | - |
| 15 | - | 0.81 |
| 16 | - | 2.93 |

Source: authors' estimates based on NIUA (2005)

Table 45: Average **c**ost of production per-cub-meter of water supply in Class -II cities

| **Typology** | **Average cost of production per cubic metre**<br>**Class-II cities** | |
|---|---|---|
| | **Surface water** | **Ground water** |
| 1 | - | 2.06 |
| 2 | 1.34 | 1.19 |
| 3 | 1.21 | 1.03 |
| 4 | 2.03 | 2.10 |
| 5 | 1.53 | 4.58 |
| 6 | 2.37 | 1.36 |
| 7 | - | - |
| 8 | 0.72 | 7.80 |
| 9 | 1.86 | 1.79 |
| 10 | 2.08 | |
| 11 | 4.56 | 4.08 |
| 12 | 3.05 | 4.70 |
| 13 | 2.61 | - |
| 14 | 2.50 | 0.93 |
| 15 | 2.44 | - |
| 16 | - | - |

Source: authors' estimates based on NIUA (2005)

The cost figures provided here cover only the cost of production and supply of water and do not include the cost of depletion of resource and cost of environmental degradation. But, as we have seen earlier, the decision concerning metering of water supplies, its volumetric pricing and investment in leakage reduction measures is based on calculation of long term marginal costs, and this should include both the latter components. Whereas for taking decisions on which water supply option is superior, the cost of production and supply of water alone will be sufficient. The reason is that the opportunity cost of using water resource (the depletion cost) and the environmental cost of degradation of water would be same for all water supply options, except desalination.

Nevertheless, the cost figures worked out here are based on 1999 figures of capital and O & M figures for water supply in different cities. Hence, they need to be revised, essentially to take care of two things: 1] inflation which raises the cost of materials used for building water supply infrastructure, and the operation and maintenance of the system; and 2] the changes in cost of production of water owing to changes in the resource environment. The second one is important for groundwater based schemes, where the increase or decrease in depth to water table can cause changes in cost of lifting of water.

## 14.2 Sewerage System Costs

The cost of a sewerage system for an urban area is determined by two key factors: 1] the length of the system per unit population; and, 2] the cost of the sewer per unit length. The first factor is a function of the population density. For cities with very high population density resulting from dense cluster of buildings and vertical growth, the length of the sewer per unit of population would be extremely low. This has been found in a research carried out by Wolfram et al. (undated) in Switzerland using an Urban Infrastructure Model (UWIM). It had: a] a catchment model to calculate the municipal sewerage pipeline lengths and diameter; and b] construction cost model, using outputs from the earlier one to estimate the total construction costs. The study involved a large number of small towns and large cities which had near to 100 per cent centralized sewerage connection. The relationship between population density and the length of the sewer (m) per unit population was an inverse power function. Here, the real time data was compared with the UWIM.

At the same time, the cost per unit length of the sewer was a logarithmic function of the population size. This was due to increased construction cost for larger diameter pipes and higher excavation needed resulting from higher density of population in larger cities (Wolfram et al., undated). This means the benefit that can be derived from having high population density can far exceed the dis-benefit due to high cost of unit length of the system. The same norm can be applied to India as: there is wide variation in population densities between cities starting from as low as 500 per sq. km to 35000 per sq. km); and cities with larger population size had higher density also (Figure 20)[42].

The Swiss study showed economies of scale in combined sewers, with the cost per unit population declining for cities with larger population size (Wolfram et al., undated). The implication of the study for urban sewerage system planning is that the zones with high population densities, a single centralized sewerage system which cover maximum area of the zone can help obtain "economies of scale". Whereas if the population density is small in a particular zone, the sewerage collection and disposal/treatment system should be decentralized to minimize the length of the system per capita. Here the cost of the system per unit length cannot be manipulated. These analyses presented above help to identify the favourable conditions for new centralized and decentralized wastewater treatment systems.

These relationships show that the cost norms for sewerage systems should be different for cities with different population densities. For sewerage system cost calculations, the population density ranges can be: a] 500-1000; b] 1000-3000; c] 3000-6000; d] 6000-10000; e] 10,000 inhabitants per sq. km and above. The average length of the system per unit population can be selected for each population density category. This cannot change significantly from the chart provided below. Subsequently, the cost per unit length can be obtained for sample cities having extreme values of population density.

The sewerage system cost ($C_{sewer}$) can be estimated as:

---

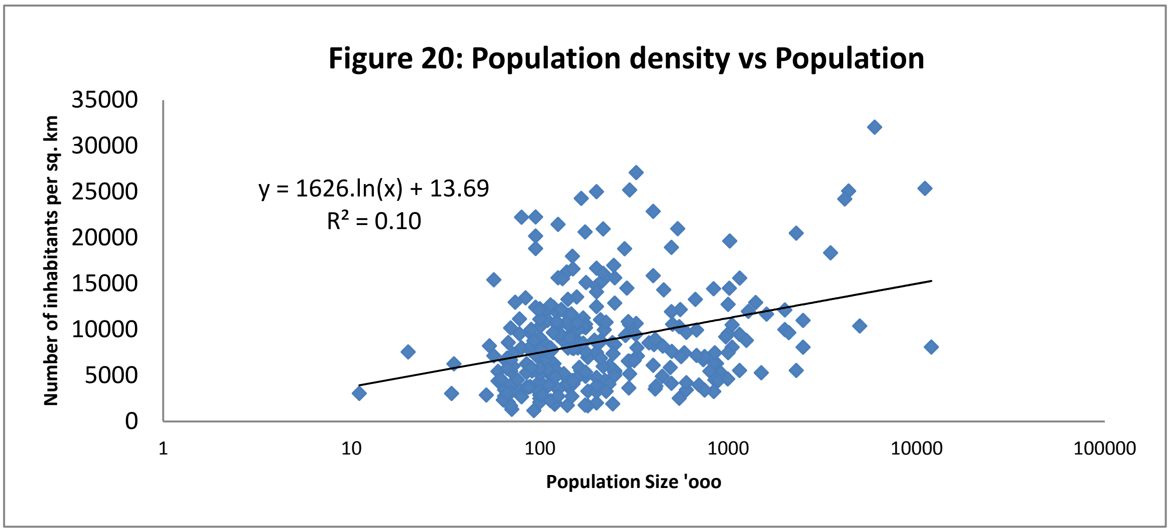
[42] The population size explained population density by 10 per cent, and the relationship was logarithmic.

$$C_{sewer} = L_{sewer-capita} * C_{unit-length} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

## 14.3 Wastewater Treatment Systems

We have seen that unlike sewerage system, the cost of wastewater treatment is a function of the type of wastewater treatment system suitable for the city, and their size. Both can vary according to the climate (temperature, sunshine), altitude, land availability, price of the land, the access to natural sinks, and the quality of wastewater. Very high price for land could force water utilities to go for expensive wastewater treatment systems like the RO systems. Higher concentration of BOD/COD would increase the cost of treatment in certain cases, while reducing in certain other cases. Presence of heavy metals would increase the treatment needs. Hence, the technology for WWT will have to be selected with due consideration to the typology in which the city/town falls in order to ensure efficacy. Once that is done, the right kind of technology will have to be selected with due consideration to their physical feasibility, economic viability, and the human resource capabilities for running the systems as we have shown earlier.

1. For WSP, the cost for treating a unit volume of wastewater will be a function of: 1] the area required for anaerobic pond, facultative pond and maturation pond, which is




determined by the temperature (as temperature increases, the area reduces); and 2] the unit price of land.

2. For ASP, the cost of treating a unit volume of wastewater will be a function of: 1] the area required for the aeration pond and the cost of producing the mechanical energy required for creating aeration, which is a function of the temperature (as temperature reduces the mechanical energy requirements reduce);

3. For SAT, the cost of the treatment system will be determined by the land area (irrespective of the climate) and land prices. The land area required will be a function of the total volume of wastewater generated per day and therefore the cost norm can be arrived at using: 1] land area per unit volume of wastewater generated per day; and 2] the land prices.

# 15. URBAN WATER GOVERNANCE

## 15.1 Introduction

Water governance refers to the range of political, legal, social, economic and administrative systems that are in place for effective management of water resources and their service delivery at different levels of society. Governance translates into political systems, laws, regulations, institutions, financial mechanisms and civil society development and consumer rights (GWP, 2003). Good water governance essentially leads to sound practice of making rules relating to water resource evaluation, water resource planning, water development, and water management (Hunter Districts Water Board, 1982; Page and Bekker, 2005).

Water governance is linked to governance of society at large--countries suffering from bad governance often have good water governance (Spanish military regime). Also, some countries' good governance had their origin in good water governance (Dutch water boards in the 19th century).

Distributed governance provides clear cut roles and responsibilities for different parties--government, private sector, civil society and individuals, with government alone not trying to solve society's problems. It is about balancing powers at various levels. For distributed water governance to work, dynamic relationships between and amongst actors, and accountability is important. In effective water governance, dialogue with and participation of stakeholders in creating conditions for good governance is necessary.

Laws should translate into regulation or working rules. Regulations should be based on incentives and capacities. Also, it should reflect the field realities rather than purely based on legal theory. For instance, making RWHS mandatory does not make sense for a region, where significant percentage of the communities do not have proper roof or the rainfall is too scanty. Similarly, enforcing an urban land ceiling act in a city which already has very high density of population would only create more congestion in the city, creating more inconvenience to the city dwellers in terms of soaring price of land and real estate.

Good governance should enable increased investments in basic water services; observe financial discipline to reduce expenditure; target at full cost recovery by raising tariffs, but safeguard poor people's access for basic needs. In order to improve governance, it is important to increase awareness about the value of water services; greater transparency in sharing information on the expenditure incurred for provision of water supply, and the efficiencies achieved in water supplies, and the non-revenue water.

Though willingness to pay exists, collection system is poor or corruption is rampant, reducing the motivation to pay. Since individual payment defaulters cannot be denied water, it is better to make the society or the cluster responsible for the payments. Citizens can therefore be given legitimate rights to complain against: defaulters in water cess payments; and illegal tapping of water.

Local water issues might be very different from basin or national/regional water issues. Hence, water should be managed at the lowest appropriate level. But, while applying the subsidiarity principle, it should be ensured that the local water management actions are linked with basin water management actions--intensive water harvesting at the local level may be against the interest of its basin-wide optimal utilization.

For it to make impacts, RBOs should have teeth. Local water councils or urban bodies or their water utilities should have representation in the river basin committees. Options for implementing reforms for effective governance should be prioritized on the basis of their political feasibility--river basin organization to be promoted in basins where uses are intensive and competing. Groundwater regulations or water rights reforms would be essential in areas where the aquifers are under severe stress.

Significant social or political changes in society can create new opportunities for increasing the effectiveness of governance--introduction of mobile phones; computerization of user data base; internet access; digital pre-paid meters; introduction of administrative reforms in national and state levels. Educating journalists is also a key to making the dialogue on water much more broad-based, and informed; which would ultimately help improve governance of water.

## 15.2 Governance of Urban Water & Wastewater Pricing

This refers to making rules relating to fixing prices of urban water supplies and sewage, which would touch upon matters such as: the norm for fixing prices; who should fix the prices; who should administer the prices; and who should have a say in fixing pricing norms; and nature of subsidies for the poor. We have discussed the norms for fixing water prices that use some sound water management principles and objectives in the section on water demand management. But, the challenge is to make sure that the estimates of cost of water supply provision, cost of depletion of the resource and the cost of resource degradation are authentic. When private agencies are involved in water supply provision under PPP or otherwise, it is necessary that the above-mentioned estimates undergo full scrutiny by an independent regulatory authority in order to make sure that the consumer interests are protected.

Australia provides the best example of urban water pricing governance. In Australia, the Essential Services Commission (ESC) appoints independent consultants to review the water plans[43] submitted by the Urban Water Businesses for the costs, and suggests allowances for efficient costing. The ESC assesses the water plans against the principles set out in the Water Industry Regulatory Order, and decides whether to approve the charges, or the manner in which these costs are to be calculated.

Subsidized water tariff is found to benefit the rich urban consumers most. Increasing block rates in volumetric water tariff would help equalize the subsidy benefits across classes.

A variety of measures can be employed to protect the poor from reduced access to water services due to high water tariff, while improving the pricing policies for water. An OECD report (2003) grouped them into two categories: income support measures and tariff-related measures. Income support measures comprise those which address the individual consumer's affordability problem from the income side, such as water bill reductions or waivers, water service vouchers from the governments, capped tariff rebates and discounts, and payment assistance. Tariff-related measures include increasing block rates, capping metered tariffs, special tariffs for low income consumers, subsidized connections to the network, and so on. Similarly, the three general approaches are used China, namely, increasing block rates, income support, and price waivers for the poorest households.

The following measures can be resorted to for ensuring good governance of water & wastewater pricing.

- In the case of private water utilities, an independent regulatory authority is involved in approving the charges, and the manner in which the various cost components" are worked out by the utility

[43] They set out the prices each of the business proposes to charge for water, sewerage and other related services.

- Sound economic principles are used for price fixing, which means the marginal cost of water supply provision, the cost of depletion of the resource and the cost of environmental degradation are taken into account.

- The norms used for fixing prices and working out the water bills are known to the consumers

- The actual cost of production and supply of water depends on the efficiency with which the utility is working. Therefore, it is imperative that the actual efficiency levels obtained by the utility is maintained at desirable levels, and also known to the independent regulatory body and the consumers.

- Income related measures are used to target the subsidies for the poor.

- Good redressal mechanism exists for the consumers to complain about the tariff and the changes independent of the utility.

## 15.3 Governance of Urban Water Infrastructure Financing

Governance of urban water infrastructure financing refers to setting rules & norms regarding: setting priorities on the type of infrastructure to be supported in urban water sector; preparing the DPRs and cost estimates; who should give the financial approval; release of funds for building infrastructure; and infrastructure building performance review process.

- **Prioritizing Investments for Water Infrastructure** using sound analysis of the hydrology, geo-hydrology and water quality parameters to ensure physical sustainability of the physical intervention, and the sound comparative economics of the proposed interventions against the several of the alternatives to ensure economic efficiency. If the cities are falling in basins which are already running out of water then, the urban infrastructure financing should give priority to activities such as leakage detection & leakage reduction measures; water metering & pricing; wastewater treatment & reuse; and integrated storm water management.

- **Creating Green Infrastructure** Funds in the state and central governments to assist municipalities in implementing strategies to reduce water use, leakage, waste water and storm water discharges through green infrastructure and innovative storm water management, such as permeable pavement, green roofs, urban wetlands and stream restoration. But, whether an infrastructure is green or not would be determined by the climate and water resource availability. In hot and arid climates, maintaining greenery on roof tops would not help in reducing wastage of storm water, but instead would increase water use as water will have to be supplied to the trees. Accordingly, the funds under this programme also will have to be administered so as to make sure that it goes to those areas where the impacts in terms of water saving and infrastructure cost reduction are maximum.

- **Develop Municipal Water Efficiency Fund** to support municipalities in the design and implementation of water efficiency programs. Such investments will optimize existing infrastructure by enabling municipalities to serve more water customers out of current inefficiencies and by delaying or avoiding costly, and often unnecessary, expansion. The funds could be used for providing subsidies to the consumers for purchase of efficient water use devices (such as low head showers and low volume flush toilets). For utilizing the MWEF, one prerequisite should be that the users are already paying for the water on pro-rata basis. Secondly, it should be made available to those who are in the segments of "low volume water use", for whom the cost saving through adoption would be very low and opportunity costs high. On the contrary, for those in the high water use segment, opportunity cost of reducing water use would be less.

- When reviewing new water and wastewater infrastructure projects from municipalities, the central government can impose conditions that water efficiency plans and programmes would be an integral part of the urban water infrastructure project, for the said municipalities to be eligible for federal funding of large-scale water and wastewater projects. Plans should be based on a goal of becoming financially self-sustaining through full cost accounting and long-term asset management.

- Implement a ***Water Efficiency Act*** that sets mandatory water efficiency standards for appliances and phases out outdated technologies.

- **Linking fund release to outcomes rather than outputs**: Traditionally ministries provide funds for infrastructure building to line agencies on the basis of the physical and financial performance and completion reports. The focus is always on the length of the distribution pipes laid out, length of the sewerage lines, and the size of the wastewater treatment plant built. There is hardly any focus on the outcome performance, i.e., how many people are additionally benefited by a new water supply scheme or the extension of the existing scheme etc. in terms of improved water security; how many people are benefited by sewerage connection, how much of the generated wastewater is collected and treated etc. Linking fund release to outcomes would create incentive for effective planning and implementation of the projects and schemes.

- Creating independent authority to review technical & financial proposals: there is a need for an independent and competent authority, outside the government, to review the technical proposals and budgets, particularly from the point of view of: 1] the soundness of the plan in terms of physical, economic and environmental sustainability; 2] robustness of the designs chosen; 3] quality of the materials proposed to be used; and the experience of the agency selected to execute the scheme. This would help prevent creating unsustainable and costly urban water solutions.

**Note:** Green infrastructure refers to techniques and systems that use the natural capacities of soil and vegetation to absorb and retain water, and to take-up, transform, or otherwise treat pollutants in water. Natural systems are found to be more cost-effective and require low building, labour and maintenance costs. They are much more convenient than the conventional (biological) wastewater plants during the operational phase, because they require less energy than conventional systems (Khatri and Vairavamoorthy, 2004).

## 15.4 Governance of Urban Water Supply

Good governance of urban water supplies means that the rules and norms regarding water supply are most user oriented; and are also known to the urban water users. These norms and rules broadly concern: per capita supply level and quality of water to be supplied for urban uses; water supply schedules; provision of new connections and fixing of connection charges; the level of awareness among the consumers about the average supply levels, quality of water and supply schedules and changes from time to time; redressal of complaints; and the "beneficial uses".

Domestic water demand is a function of socio-economic status including per capita income levels, which determine different water needs of the household, climate, and price of water. This means that for good governance of water supply, the norms regarding per capita supply levels and quality of water should be worked out on the basis of the climatic conditions and the socio-economic status of the dwellers, keeping in mind the highest quantum that users are willing to buy at the prices that exist.

For fixing norms about water supply levels, scientific studies for water demand estimation for different income segments and for the given climate would be important. This is because domestic water demand is a function of income levels and climate. While it increases with increase in income till a point and then flatten (Rosegrant et al., 1999), it would be higher in hot tropical climates. Also important are the estimates of price elasticity of water demand for different pricing regimes and for different income levels and climatic conditions. The reason for this is that the climate and income levels have bearing on the price elasticity of urban water demand, as shown by studies internationally. The price elasticity of water demand would be lower for higher income groups. Also, for hot tropical climates, the response of consumption to price changes would be lower.

As regards provision of new connections, the norms regarding the connection charges and "maximum waiting time" for different zones, the procedure for application and the eligibility criteria should be made public.

For supply schedules to be user friendly, they need to be worked out on the basis of proper scientific assessment of the schedules that are convenient for the consumers, and are known to them in advance. This would help them make necessary arrangements. If the schedule changes, that should be communicated to the consumers well in advance. As regards redressal of complaints, clear cut timeframe should be fixed by the municipal authority or water utility in consultation with the technical department for attending to each type of complaint, and this should be known to the consumers.

For greater consumer satisfaction, it is necessary that the users know the quality of water being supplied to them. This is more so in the formally educated and progressive communities. The utility should have clear cut rules regarding the type of information on water quality to be shared, the frequency with which the information is shared with them, and platforms used for making it available to the public and consumers.

The criteria used for defining certain water uses as "beneficial" should be revealed to the public, and if penalties exist for uses other than beneficial, that also should be known to the water users through public awareness campaigns using mass media.

## 15.5 Measures for Pro-poor Governance of Urban Water

The Indian city of Bangalore is showing how external forces can influence a water utility to begin responding to demands from slums for improved performance and accountability[44]. Another example is from Suryapet of Andhra Pradesh. Some of the steps in this direction are:

- Establishing phone and on-line complaint systems
- Consumers have a say in fixing priorities regarding the beneficial water uses and non-beneficial water uses in urban areas
- Reducing unaccounted for water through a leak reduction programme: technological interventions
- Incremental block rates: Increasing the tariff rates but reducing the rate for the minimum amount people have to consume
- Holding engineers accountable, if they fail to respond to complaints
- Convening monthly meetings to give city residents the chance to talk with engineers
- Establish a social development unit for slums
- Working with slum dwellers and their representatives to determine priorities and jointly verify that connections are actually installed.
- Providing water supply & sewerage connections at highly subsidized rates for families belonging to BPL category.

### 15.6 Governance Mechanisms for Improving Sanitation for Urban Slums

Mostly urban slums are created by the influx of people from rural areas who come to cities in search of employment. They work as construction workers or unskilled daily wage labourers, and set up their temporary shelters around their work sites. These slums create major environmental sanitation problems as they defecate in the open and are not able to access safe water supplies from public water supply systems. This not only affects the health of slum dwellers but also the people living in neighbouring housing societies. Often, urban surface water bodies such as lakes, ponds and tanks are used for flushing out human waste, contaminating not only these water bodies but also the groundwater. The very fact that the construction sector gets these labourers cheap, while the negative externalities due to the same are being borne by the urban community at large, makes it mandatory for the construction sector to pay for provision of sanitation services. Such costs can be built in the costs of urban infrastructure projects.

The official sanctioning of urban infrastructure projects by the urban local bodies should be subject to provision of water supply & sanitation services for the construction workers in the development plan itself, and starting of any construction should be subject to certification by the concerned authority of completion of such works. This essentially means improving the governance of urban sanitation would require modifying urban infrastructure bylaws.

## 16.0 SOME BEST PRACTICES IN URBAN WATER MANAGEMENT

- Providing subsidies to the poor in getting water supply & sewerage connections (Habitat, 1997)

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44 Three pilot projects funded by the Australian agency AusAID demonstrated that water could be piped to slums legally; contractors can work in slums under supervision; residents are willing to pay for improved supply; and the traditional problem of lack of tenure can be managed. ID21 summarised a paper [1] from the Massachusetts Institute of Technology in the USA.

- Increasing the number of water supply & sewerage connections, including regularizing of the illegal connections: by doing this not only the overall revenue collection increases, the chances of illegal tapping reduce. This minimizes the non-revenue water. It also reduces the pressure on the utility to increase the water charges to recover the costs.

- 24 x 7 water supply reduces the overall energy consumption for pumping water. This reduction would be quite significant in areas which have independent bungalows and houses.

- Improving the functioning of meters, accuracy of taking meter readings, and proper billing

- Providing enabling legal and institutional frameworks for urban communities to meaningfully participate in UWM

## 17.0 POLICIES AND LEGAL FRAMEWORK FOR URBAN WATER MANGEMENT

### 17.1 Policies for Sustainable Urban Water Management

Many policies governing urban water management in India are uniformly applied across the cities without much consideration to their outcomes and impacts. Many states follow uniform pricing policies for urban water, irrespective of the differences in water endowment across regions and urban centres. Policies to encourage rainwater harvesting such as provision of subsidies for construction of tanks by housing stocks do not take into account the overall social costs and benefits, and whom they benefit. Uniform norms are followed for effluent disposal and pollution control across Indian cities by the Central Pollution Control Board, without any due consideration to the ecosystem carrying capacity.

We have already seen that different regions in India have different water resource conditions, and ecosystem carrying capacity. The groundwater resource availability also varies drastically from the indo Gangetic alluvium to the mountainous areas of north east. The urban population density varies remarkably across cities from as low as 500 persons per sq. km to 30,000 persons per sq. km. Therefore, uniform policies across cities and towns irrespective of the physical, socio-economic and political environment will not yield desirable results in terms of improving urban water management; be it policies governing water use by consumers; policies governing effluent disposal; environmental sanitation; or urban growth. Policies governing water use have to take into account the water endowment, i.e., whether water is scarce or abundant in the town/city under consideration.

Policies governing storm water use have to take into account the hydrological regime of the area. Policies relating to effluent disposal have to consider the carrying capacity of the surrounding ecosystem. In sum, policies relating to urban water management have to be based on the complex considerations such as ecological carrying capacity, urban population density, water resource endowment and type of pollution that urban areas experience in order to ensure sustainable urban water management.

The type of policies relating to urban water management (policy objectives), the typologies for which they are applicable and the policy actions are summarized in the Table 45.

Table 45: Urban Water Management Policies: Objectives and Actions for Different Typologies

| Sr. No | Type of Policies | Typologies | Policy Actions |
|---|---|---|---|
| 1 | Policies to encourage rainwater harvesting | Any urban area where the cost of production & supply of water is higher than the cost of RWH tanks | Subsidies to be provided for constructing RWH tanks; full cost pricing of public water with volumetric charges |
| 2 | Policies to encourage runoff reduction | Very high rainfall, plain areas, including those prone to floods | Taxes for housing stocks without RWHS, and tax benefits for those having it |
| 3 | Policies to encourage water conservation at end user level | Water-scarce cities/towns, and large cities | Water metering & volumetric pricing |
| 4 | Policies to reduce unaccounted for water | Water-scarce towns, and all large cities | Water metering & pricing |
| 5 | Policies to discourage water consumption for low valued uses (gardening, swimming pool) | Water-scarce towns, and large cities | Incremental block rates |
| 6 | Policies to encourage excessive consumption | Water-rich areas, but with WS infrastructure having excessive capacity | Declining volumetric prices with increasing use or fixed charge |
| 7 | Policies to encourage waste water reduction | Cities with very high land prices; cities where high concentration BOD is needed for energy recovery | Volumetric sewerage charges |
| 8 | Policies to reduce toxic waste reduction at the manufacturer level | Areas where industrial units are heterogeneous | Stringent pollution control norms |
| 9 | Policies to discourage horizontal city expansion | Cities with very low density, and with water scarcity | |
| 10 | Policies to encourage groundwater use | Cities falling in groundwater abundant areas | Subsidized electricity for domestic & municipal pumping of groundwater |
| 11 | Policies to discourage groundwater withdrawal for municipal uses | Cities where groundwater depletion is causing environmental degradation | Groundwater abstraction tax to be kept higher than the unit price of supplied water |
| 12 | Pro poor policies for water supply | Water-scarce towns and large cities | Subsidized tap water supply connection charges |
| 13 | Pro-poor centralized, environmental sanitation services | Areas vulnerable to groundwater pollution*, particularly those in the urban | Subsidized connection charges for centralized sewerage system for |

| | | | |
|---|---|---|---|
| | | fringes | poor families, |
| 14 | Pro-poor decentralized sanitation services | Areas "least vulnerable to groundwater pollution" + other areas in urban fringes | Subsidies for toilet with septic tank construction |

Source: based on authors' own analysis

Note: Vulnerable, highly vulnerable and very highly vulnerable

## 17.2 Urban Bylaws and Legal Framework

### 17.2.1 Model Municipal Law, 2003

Model Municipal Law (MML) was drafted by MoUD & PA (now MoUD), to assist urban local bodies in the areas of: a) financial reforms, comprising accounting reforms, and resource mobilization; and b) private sector partnership. The major focus of the MML is on simplification of municipal bylaws to enable: enhanced borrowing; entry of private sector; and authorizing concessionaires to penalize users for non-payment of water tariffs. As per the recommendations made under MML, many state governments including Uttarankhand, Orissa, Delhi Municipal Corporation and Andhra Pradesh initiated amendment of their municipal laws (NIUA, 2003).

The background behind MML, however, narrates an interesting story. MML was drafted through a USAID-sponsored process under its Financial Institutions Reforms & Expansion (FIRE-D) program. Within the ambit of FIRE-D are the whole range of urban infrastructure and services, in particular promotion of private sector participation in, and methods for drawing private funds into, urban development. Thus it can be interpreted that MML specifically addressed the concern for commercialization of selected urban and civic services and private sector participation.

Experts believe that the MML was drafted to facilitate implementation of public-private-partnership (PPP) for development, management and financing of urban infrastructure under JNNURM. The belief stems from the fact that most of the state municipal laws restrict entry of private sector in the provision of municipal services, including water supply and sewerage services. Thus under the JNNURM there will be enormous pressure on the states to adopt MML or amend existing legislation so as to enable urban sector reforms to meet the conditionality for flow of funds from the centre (Raghu, 2005).

The model municipal law, however, does not have provisions to ensure sustainable use and management of water resources, including protection of natural quality of water. It also does not have provisions for protecting the consumers from false billing, penalizing people and agencies for illegal tapping of water, which are crucial issues facing sound financial working of the water utilities in urban area. Neither does it provide legal teeth to agencies such as the pollution control board for taking legal action against polluters. Over and above, a uniform legal and regulatory framework cannot be enforced in different municipal situations effectively. The nature of law or regulations has to be decided on the basis of the socio-ecological environment prevailing in an area.

### 17.2.2 Enabling Bylaws for Sustainable Urban Water Management

**Urban Land Ceiling Act**: The single most important legal intervention in the urban areas for improving the performance of urban water management systems is the enactment of an urban land ceiling law. The aim of the proposed urban land ceiling law should be to prevent unscrupulous lateral growth of urban areas, particularly in cities/towns which have very low population density[45]. It can achieve this objective by providing for imposition of differential taxes on new developments and old developments by the urban local body. The building tax for new developments could be kept at a much higher level than that for old ones. Further, the license for housing stocks and other developments in new areas should be subject to them managing their own water supply, wastewater disposal/treatment and storm water drainage systems. This can prevent un-economic and inefficient expansion of urban water and sanitation infrastructure. However, preferential treatment will have to be given to urban areas which have high population density, i.e., above 15,000 persons per sq. km.

**Building Bylaws**: In very high rainfall plains as well as hilly areas, the building bylaws should provide for provision of separate rainwater storage tanks by new constructions. The building bylaws should be made such that only those new constructions which have provided for underground storage tanks, with capacity proportionate to the size of the roof, is given license to construct. The completion certificate shall be issued by the competent authority only after site verification to see whether the proposed construction is built as per the plan approved by the urban local body. Disincentive could be created for old constructions, which are not complying by the new building bylaws, in the form of additional taxes.

Another bylaw will be with regard to built up area. This is applicable to all high rainfall areas and those prone to floods. In such areas, apart from providing for roof water collection tanks, the new constructions should provide for rain gardens, in proportion to the total built up area. This would help reduce the storm water runoff generation in those areas, reducing the chances of urban floods.

**Legal Framework for Metering System**: There are many cities in India which have adopted metering of water supplies, either partially or fully. But, there are very few cities where metering system is working efficiently. Complaints from consumers about over-reporting of consumption owing to false meter reading and malfunctioning of meters are quite rampant in many cities. On the other hand, incidence of tampering is meters are encountered in many cases (World Bank/GOI, 1998). In order to make pricing based on water metering efficient and smooth, there is a need for a strong legal framework. The legal framework should provide for: 1] protection of consumers against false metering and charging false bills; 2] penalizing of consumers who tamper with meters to protect the utility interests; 3] consumer right to ask for timely replacement of malfunctioning meters; 4] creation of special testing labs for proper functioning of meters; and, 5] protection of meter readers from physical assault by errant consumers. Water being a state subject, the concerned states should frame bills in this regard and enact it to make it a law.

**Water Resource Regulatory Act**: Researchers for long have argued that for sustainable water resource management, the agency responsible for water allocation should not be same as the agency using the water (Frederiksen, 1998; Kumar, 2006). Separating out the water resource management functions from water service functions would create conditions under which the utility (the water supply agency) would be confronted with opportunity cost of using the water. The Water Resources Regulatory Act, being proposed here, is to provide for establishment of tradable water rights and creation of RBOs as legitimate organizations for

[45] It is evident from the analyses presented in this report that large geographical area and low population density are leading to poor physical, economic and staff efficiency in urban water management systems.

fixing and allocating water rights, and its enforcement, and regulation of water quality. Currently, only one state in India, i.e., Maharashtra had a Water Resources Regulatory Act of 2005, and this Act had provided for the establishment of a Water Resources Regulatory Authority. There are legal provisions under this Act, for setting up of river basin organizations (RBOs).

As per the Maharashtra Water Resources Regulatory Authority Act (2005), River Basin Agencies issue bulk water entitlements based on the category of use (irrigation water supply, rural water supply, municipal water supply or industrial water supply) and subject to the priority assigned to such use under State Water Policy (MWRRAA, 2005). Further, it was stipulated that the existing Irrigation Development Corporations (IDCs) should function as River Basin Agencies. But currently, IDCs are only responsible for survey, planning, design, construction and management of Major, Medium and Minor Irrigation Projects, and irrigation water services. Hence, the new arrangement is likely to protect the entrenched interests of irrigation Corporations to over-allocate water for the sector it is concerned with, which is against the principle of sustainable water resources management in the river basin.

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