Decentralised Options for Urban Water Management

A Guide Book

TARU

TARU Leading Edge

Gurgaon and Gandhinagar, India

Message

Indore city, situated in semi-arid upper catchment region, is facing serious water challenges. Recurrent droughts are major issue of this area. The oldest water systems of Indore relied on rainwater harvested through Bilawali and Yashwant Sagar as well as thousands of traditional wells. As the city population grew, the water footprint of the city expanded much beyond the city limits and we have been augmenting the water supply system from distant Narmada River from time to time. Situated at about 70 km away with a pumping head of more than 500 m, Narmada water supply is costly. Efficient water management is critical for sustainability of the city. While we augment our supply from Narmada River, it is also necessary to explore and develop decentralized solutions to meet growing demands by conserving the local resources and recycling of water. These measures only can increase resilience of our water systems against climate change and increasing demands.

Over exploitation and deteriorating water quality of ground water and pollution of lakes are major challenges that we face today. The "Indore City Resilience Strategy" document has highlighted the growing challenges of climate change on our water resources.

As we face the twin challenges of rapid urbanization and climate change, we have realized the need for paradigm shift in water management of the city to face 21st Century challenges in urban water sector. There is urgent need to conserve the local resources as well as improve the efficiency of water use. Indore was the first city in India to incorporate rainwater harvesting in building regulations.

This is a moment of great pleasure for Indore city to release the "Decentralized Options for Urban Water Management – a Guide". This Guide aims to build awareness of water challenges and highlights need for managing water across scales ranging from households to city levels. It provides water management options including rainwater harvesting, ground water recharge, and recycling and water quality improvement. I hope that this guide will help in engaging people in local water resource management to strengthen the linkage between people and local water resources. It opens up opportunities to improve efficiency of city water systems as well as build resilience against climate change related uncertainties.

I believe the guide will help planners, policymakers, organizations and the managers to think about emerging options for proactive involvement of user communities in urban water management. I hope that this guide will inspire them to develop policies and institutional mechanisms to deal with urbanization and Climate Change related water challenges. I thank Asian Cities Climate change Resilience Network and Rockefeller Foundation for taking up this initiative in Indore.

(Krishna Murari Moghe)
Mayor
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TARU

Foreword

The urban water systems face challenges of high leakage losses, wastages and pollution resulting in damage to local resources (e.g. Lakes, groundwater). The total reliance on centralised water supply system has given a false sense of security, which is belied especially in cities facing rapid urbanisation. The household / colony level coping measures in poor / informal settlements and peri-urban area provide partially solutions like ground water usage resulted in groundwater over-exploitation also has water quality issue. Lack of proper sewerage has resulted contamination of aquifers through waterlogging and sewage flow in the natural drain and adverse health impacts by use of contaminated water.

Rapid urbanization and peri-urban growth are being experienced in most of cities in developing countries like India. This leads to lag between demand and supply, especially in resource scarce environments. As the water footprints of the cities grow, they need to pump water from increasing distances. Increase in proportion of paved areas alters the hydrology of urban catchments with increasing peak discharges and pluvial floods.

Climate change is likely to amplify the scale of water scarcities by intensification of uncertainties in precipitation patterns and increased per capita demands of water due to temperature increase. Increasing variability in rainfall is expected along with dominance of extreme rainfall events, longer dry spells and droughts. These can amplify urban floods as well as seasonal scarcities. The impacts of water scarcities are especially felt in poor and informal settlements with limited access to piped water supplies, peri-urban areas where the supply network is not extended.

Integrated management of urban water system; water supply, sewerage and storm water can reduce the dependence on external sources and can also increase resilience of water systems against power failures, variability at source level and seasonal scarcity. To optimise use and minimise costs, water systems need to be managed across scales including households, colonies and township levels. The connection between water and users need to be re-established through their active involvement in conservation and management.

This guidebook provides methods of developing options for decentralised water management systems based on local sources. It is aimed at creating awareness about conservation of local resources and to guide the implementers of decentralised urban water systems. It is specially address water issues commonly faced in poor, informal and peri-urban settlements.

The guidebook is aimed at exploring options for conjunctive management of local and distant water resources to increase resilience of urban water systems. It can be used as a guide to understand the water resource and demand situation at various scales to identify options for water management. Several technical options are provided to improve efficiency of water systems across scales.

The Asian Cities Climate Change Resilience Network Programme has supported TARU to improve resilience of poor communities through conjunctive water management (CWM). This programme is supported by Rockefeller Foundation. This guide is based on the lessons learnt from the CWM project implemented in the city of Indore, India. We thank ACCCRN for providing an opportunity to explore these issues and supporting this project.

(G. K. Bhat)
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Table of Contents

List of Tables

List of Figures

List of Annexures

Abbreviations

ACCCRN	Asian Cities Climate Change Resilient Network
BOD	Biological Oxygen Demand
BIS	Bureau of Indian Standards
CGWB	Central Ground Water Board
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Organization
CCA	Community Context Analysis
CCA	Community Context Analysis
CWM	Conjunctive Water Management
CUM	Cubic Meters
CSO	Central Statistics Organization
DEFENDUS	Demand Focused End Usage
EWS	Economically Weaker Sections
FGD	Focused Group Discussions
FGD	Focused Group Discussions
GIS	Geographical Information System
GPS	Global Positioning System
JnNURM	Jawaharlal Nehru National Urban Renewal Mission
LPCD	Litres Per Capita per Day
MoU	Memorandum of Understanding
MDG	Millennium Development Goals
NIH	National Institute of Hydrology
NAFEN	National Foundation of Indian Engineers
NSSO	National Sample Survey Organization
NOC	No Objection Certificates
NGOs	Non-Governmental Organizations
O&M	Operation & Management
PGIS	Participatory GIS
SEC	Socio-economic class
TDS	Total Dissolve Solids
UN	United Nations
UFW	Unaccounted for Water
UNFCC	United Nations Framework for Climate Change

About the Guidebook

Most of the cities in developing countries like India experience rapid urbanization and peri-urban growth. Amongst other issues, this leads to a gap in the capacity of centralized water supply systems and the growing demand, giving rise to water shortages. The impacts of water scarcities are especially felt in poor and informal settlements with limited access to piped water supplies and peri-urban areas where the supply network is yet to be extended. As long as there is no surplus water available for the core city, the peri-urban and poor settlements may not be able to access the centralised supply and get a reliable water supply. Individual households, colonies and urban local bodies take several coping measures such as reliance on bore wells and tanker supplies, but these can only be a short term solution which may even have adversely impacts on public health from use of contaminated groundwater.

Water scarcity and differential availability issues are likely to exacerbate due to rapid urbanisation. Climate change is likely to amplify the scale of these problems through additional uncertainties in precipitation patterns and increased water demands for managing high temperatures. Many of the traditional sources of water are neglected or are damaged due to dumping of sewage and solid wastes or they are encroached upon. Decentralised management of water can contribute towards improving resilience of the water supply systems to these changes; prevent impacts of pollution on health and over-extraction damaging these local resources. Since the water footprints of urban systems are larger than the city area, use of external water resources is necessary but decentralised water management can meet part of the demand, especially during seasonal shortages and emergencies.

This guidebook presents options for community managed decentralised water management systems to supplement external source based water supplies. It is aimed at creating awareness about these issues and guide the implementers of decentralised urban water systems. It is not prescriptive and only provides directions for implementing decentralised urban water management projects. It specially addresses water issues commonly faced in poor, informal and peri-urban settlements. While this guide is prepared for addressing situations prevailing in India, it can be adapted to cities in other developing countries. In the interest of simplicity, only a few technical terms are used. However, it is suggested that experts are consulted wherever technical support is necessary.

The guidebook first provides an overview of the water supply & sanitation services situation of the poor in urban areas and the issues experienced at the city and settlement level. By highlighting the national and city level water management issues, it stresses the need for conjunctive management of local resources.

The next section provides a Conjunctive Water Management Framework for effective supply side management of resources. It also provides a demand focused end use framework.

The last section describes methods for analysing settlement level water resources, analysing demand and further assessment of future demands. This exercise would require some expertise and data inputs. While this guide provides an overview of methods, it is suggested that during actual studies, support is taken from academic institutions, technical departments of ULB and state governments wherever necessary. Criteria for shortlisting of technologies as well as relevant technology details are provided.

Water resource availability, willingness to adopt local systems and affordability of the communities/households vary greatly across cities and each situation is scale and community dependent. It is beyond the scope of this guide to address this variability, so an indicative implementation process is described. It is suggested that the implementation team should take care to adapt the implementation process based on the local context as well taking into consideration the team expertise.

Asian Cities Climate Change Resilience Network Programme has supported TARU to improve the resilience of poor communities by developing conjunctive water management (CWM) options. This programme is supported Rockefeller Foundation. This guide is based on the lessons learnt from the CWM project implemented in the city of Indore, India. We thank ACCCRN for providing an opportunity to explore these issues and for supporting this project.

Urbanisation – Water Linkages in Development Countries

1 Urbanization - Water linkages in developing countries

This introductory section highlights various issues related to urban water and stresses the need for managing the local resources, especially to build the resilience of urban poor to climate change impacts. It also explains the causes and impacts of water scarcity in urban areas. The purpose of this section is to provide the context and insight into multiple dimensions of urban water supply issues to the reader. While this section focusses on the Indian urban water situation and prospects, most of the issues are common for many developing countries undergoing rapid urbanisation.

Better employment opportunities, health and education facilities in urban areas are major driving forces for the rural-urban migration that accelerate urbanization. Population projections by United Nations indicate that more than 50% of the Asia's population will be residing in urban areas by Year 2030.

High land prices and limited open spaces for more construction to accommodate increasing population are leads to periphery growth and urban sprawls. Subsequently villages surrounding the cities become urban and Desakota[1] regions grow. The city administrations in developing countries are unable to provide lifeline infrastructure coverage both to the dense core as well as the peripheral areas. Water supply & sewerage networks and solid waste disposal which are the most important services are not available in peripheral areas as well as poor settlements. New informal settlements grow along marginal lands including river banks and government lands further increasing loads on existing lifeline infrastructure. Lack of tenure and identity proofs are barriers that prevent the poorer residents of these areas from getting water connection from the centralized water supply system. These issues related to lifeline services are similar in most of the cities of developing countries. To provide a context and indication of the scale of issues facing the Indian cities, the following section analyses the urban water challenges facing the country now and expected changes over coming decades.

1.1 Water Resources

India is a tropical country with average annual rainfall of about 1,000 mm most of which occurs during four monsoon months. The Indian subcontinent exhibits high diversity in physiographic conditions ranging from the Himalayan Mountains with permanent snow cover to coastal plains.

The Indo Gangetic alluvial plains are some of the most fertile plains with highest population densities and include the two metropolitan cities of Delhi (16 million) and Kolkata (14 million). Poor water quality is a major issue in this region. The semi-arid peninsular plateau with hard rocks has many large cities including Hyderabad, Bangalore and Pune and Nagpur. These cities are mostly located in upper catchment areas with limited water resources nearby and face serious water shortages, especially during

[1] **Desakota** is a term in urban geography used to describe areas in the extended surroundings of large cities, in which urban and agricultural forms of land use and settlement coexist and are intensively intermingled.

summers. The western coast has Mumbai (18 million) a metropolitan city located in humid region with a small strip of coastal plains, with the Western Ghats forming the catchment boundary. Cities in this region draw water from neighbouring small west flowing rivers, which is insufficient as the cities grow. As the cities grow, they have to source water from distant small rivers. On the drier eastern coast, Chennai (8.7 million), located in granitic hard rock terrain, has been facing perpetual water scarcity due its location in a small basin. Diversity in climatic, physiographic and geological conditions results in various water resource contexts, which necessitates diverse approaches to meet growing urban water demands.

The Ministry of Water Resources has estimated the annual replenishable water resources in the country as 1,953 km^3 spread unevenly over 3 million sq.km of the geographic area. Nearly 62% or 1,202 km^3 of the total water resources is available in the Ganga-Brahmaputra-Meghna basin (0.8 million sq.km), while the remaining 23 basins (2.4 million sq.km) have only 751 km^3 of the total water resources. Most parts of peninsular basins are located in the hard rock regions and therefore have low aquifer storage and also most of the rivers are seasonal.

Only a part of the replenishable water resources can be actually utilised. Utilizable water resources depend on the feasibility of storage and diversion structures in different parts of the basin. The utilisable water resources data is presented in the following Table 1.

Table 1: Replenishable and utilizable water resources of India

Annual replenishable water resources	1,953	Cu.km
Utilizable surface water	690	Cu.km
Utilizable Groundwater	433	Cu.km
Total utilizable water resources	1,123	Cu.km
Rainfall equivalent of utilisable water resources	370.00	mm

Source: MoWR, 2006

The water demand has been growing due to population, industrial and agricultural growth. India is rapidly transforming from a rural agricultural economy to an urban secondary and tertiary sector dominant economy. As per capita incomes grow, the aspirations and water demands also grow. Water resource demand estimates over coming decades are presented in the following Table 2.

Table 2: Estimated Water Demand projections

Sectors	**Water Demand in km^3 (or BCM)**					
	Standing Sub-Committee of Min. of Water Resources			**National Commission on Integrated Water Resource development**		
Year	**2010**	**2025**	**2050**	**2010**	**2025**	**2050**
Irrigation	688	910	1,072	557	611	807
Drinking Water	56	73	102	43	62	111

Table 2: Estimated Water Demand projections						
Sectors	Water Demand in km^3 (or BCM)					
	Standing Sub-Committee of Min. of Water Resources			National Commission on Integrated Water Resource development		
Year	**2010**	**2025**	**2050**	**2010**	**2025**	**2050**
Industry	12	23	63	37	67	81
Energy	5	15	130	19	33	70
Others	52	72	80	54	70	111
Total	813	1,093	1,447	710	843	1,180

Source: MoWR, 2006

With only 1,123 km^3 of utilizable water resources, the water availability situation is reaching a critical point and the water demand is expected outstrip utilizable resources. By 2025, the estimated per capita water availability is estimated to reduce to 814 cubic meters (NIH). This signals an urgent need for increase in water use efficiency across all sectors as well as to ensure ecological flows in the seasonal rivers.

As per the National Water policy, drinking water is given the highest priority followed by agriculture. Currently 5% of the utilizable water resources are allocated for drinking water. By 2050, drinking water demand alone is going to rise to nearly 7% of the utilizable water resources. As the population is increasingly concentrated in cities, the point demands of the cities would outstrip water resource availability in the neighbourhoods. This problem is already being faced by most cities, with cities resorting to pumping water from distant sources. Cities also import virtual water as food grains. The following Table 3 presents the indicative water requirement of a city of 1 million population considering average per water resource availability per sq. km at country level.

Table 3: Indicative Annual Water requirement for 1 million population city		
Rainfall equivalent of utilizable water	340	mm
Annual Domestic water requirement	49.28	m.cu.m
Area required for meeting water demand	145	sq.km
Food requirement @ 150kg/capita/year	0.15	m. tonne
Virtual water content of rice	2.5	cu.m
Virtual water requirement for meeting food needs	375	m.cu.m
Area required for food production considering utilizable water	1103	sq.km
Total area required to meet virtual and domestic water	1,248	sq.km

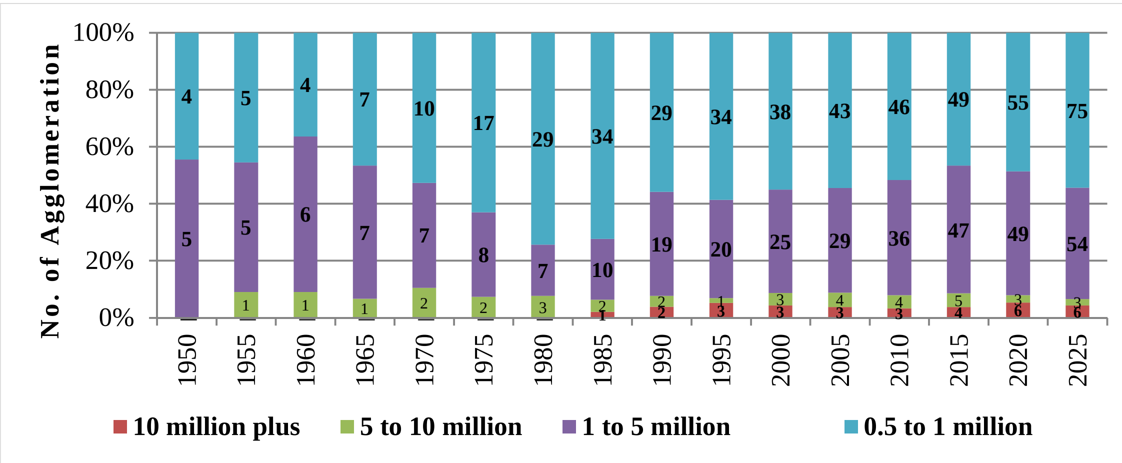
Source: TARU Analysis, 2012

The actual utilisable water resources in semi-arid and arid zones are much less than the national level average utilisable water resources per sq.km. It implies that more area is required to support water demands of the cities in such regions. While the food can be imported, domestic water demand has to be met from within reasonable distances. Many cities like Bangalore and Hyderabad are already transporting water from sources located more than 80 km away. The actual water cost (including energy costs for pumping) is more than 50 Rs. /kilolitre in case of Bangalore. The growing energy costs and increasing competition over resources increase challenges of management. Since drinking water is highly subsidised, growing losses make additional capital investments as well as water conservation works more challenging for the local government. While urban water management is poor, the cities have limited mechanism to regulate water use and encourage conservation. They have not been able to use soft paths to water management such as leak reduction, wastewater recycling to meet low end demands as well as use cheaper local resources to supplement water imports. Instead, of improving the efficiency of local resources and distribution systems, the cities opt for knee jerk actions like augmentation of capacity from distant sources from time to time.

1.2 Urbanisation

The population of India, as per Census 2011, was 1.21 billion out of which 377 million people (30% of the total population) were urban. The UN population division estimates that 41% would be urban by the year 2030 (UNDES website). The Figure 1 presents Indian cities under different population classes since 1950.

Figure 1 : Numbers of urban agglomeration in India since 1950

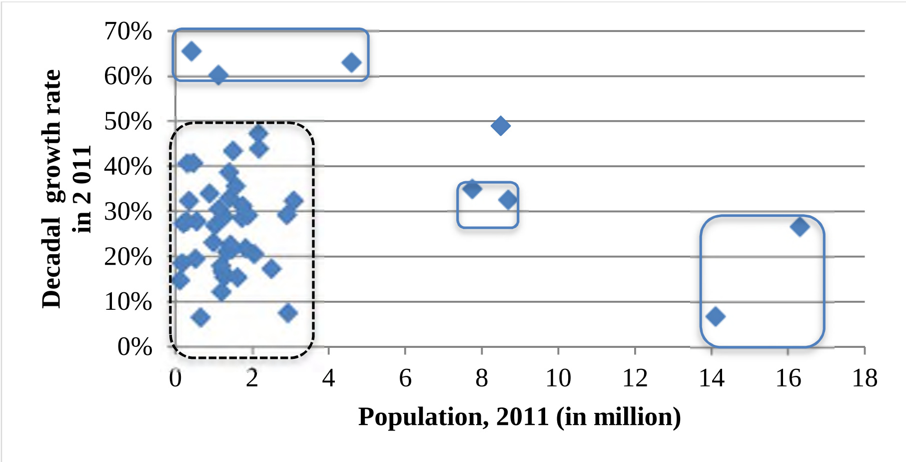


Source: UNDES website, TARU Analysis, 2013

As per the census 2001, there were 384 urban agglomerations in India. These increased to 474 in 2011. By 2015, nine cites would be having more than 5 million and 47 cities over a million. A city of one million on an average requires about 135 million litres of water per day. Annual requirements would be about 50,000 million litres or 5000 hectare meters. Considering the 5% of water resources (available water resources is roughly about 30% of rainfall) allocated for drinking water, an area of 3,000 sq.km of area is required to support the city with 1,000 mm of rainfall. Majority of the cities lie in semi-arid regions with less than 800 mm of rainfall. To address the variability in rainfall conditions, significantly more area is required to support the city water supplies. Cities create large point demands in regions where water resources are limited and the current users have rights over existing resources. Water conflicts between regions and between urban and rural areas are already being reported. With the increase in water demands, these conflicts are expected to grow. The larger the city, more such conflicts can be expected, especially in semi-arid and upper catchment cities. Even in the Gangetic plains, Delhi which is sourcing water from the main Ganges river basin from Uttar Pradesh has an on-going conflict with the upper basin state of Haryana.

The average decadal growth rate of cities observed during 2001-11 in India is about 31%. The decadal growth rate of 40 important Indian cities during 2001-2011 is presented in following Figure 2.

Figure 2: Decadal population growth rates in important cities of India in 2011



Source: Census of India 2011; TARU Analysis, 2013

Majority of the cities with populations between 1 to 4 million reported decadal growth rates in range of 15% to 50%. Two metro cities i.e. Kolkata and Delhi have witnessed decadal growth rate of 7% and 27% respectively, which is less compared to other cities. Actually, high population growth was reported from new agglomerations in their periphery (e.g. Gurgaon, Ghaziabad, Noida and Faridabad in case of Delhi) and the actual population growth of these metro cities has spilled over to these peripheral towns making Delhi an urban agglomeration with population more than 15 million. If these are taken in to account, the Metro cities also show population growth in the range of 40-50%. Cities with populations of less than 5 million are growing more rapidly. In all these cities, population growth is not matched by improvement in lifeline infrastructure.

1.3 Water supply and sanitation status in urban India

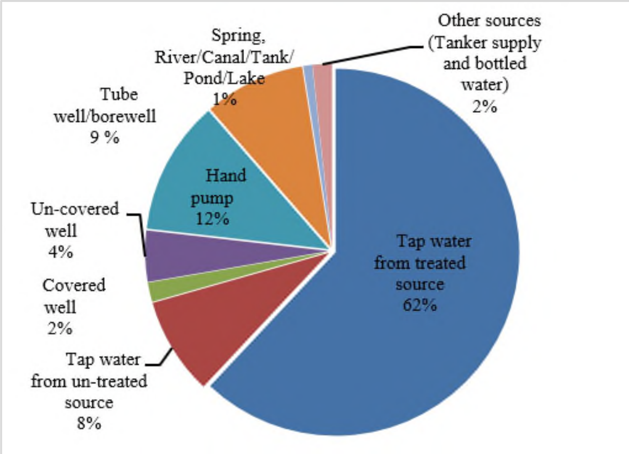
All the cities in India have centralized water supply systems. Since water scarcity is prevalent, a variety of water sources are also being used. These are by either managed by the households or by the urban local bodies. The Census 2011 reports water supply arrangements under following categories:

1. Tap water from treated source (mostly centralised systems managed by the ULBs)
2. Tap water from un-treated source
3. Covered well
4. Un-covered well
5. Hand pump
6. Tubewell/borehole
7. Spring
8. River/canal
9. Tank/pond/lake

10. Other sources (Tanker supply and bottled water)

In 2011, about 62% households in urban areas were getting tap water from treated sources and 8% households from un-treated tap water source (Figure 3). Bore wells and tube wells were used by 9% of urban households. Hand pumps were used by 12% households.

Figure 3: Distribution of drinking water sources in urban areas of India



Source: CPHEEO, 2011

The 65th round of National Sample Survey Organization (NSSO) study on household level amenities survey was conducted in 2008-09. Table 4 presents the summary of the results.

Table 4: Drinking water status availability in urban areas of India

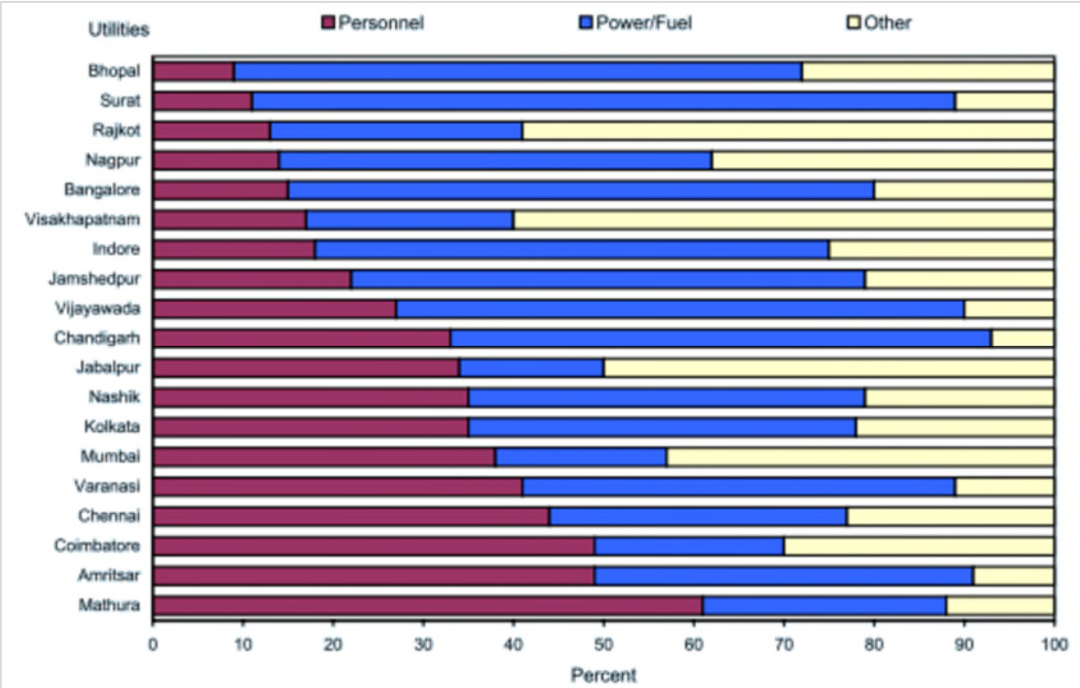
Particulars	% of urban households
Households by type of source	
Drinking water from tap water source	74%
Drinking water from borewell/hand pump	18%
Other sources	8%
Seasonal scarcity of water in summer (April to June)	6% to 8%
Households' access to water by distance	
Households having access to water supply within their premises	75%
Households with water sources outside their premises within 200 m distance	23%
Households with water sources > 200 m distance	2%

Source: NSSO, 2010

More than one fourth of the households depend on groundwater and other minor sources. Among the lower socio-economic classes, mainly women and children collect water from the distant and common sources (stand posts). The time and energy wasted has significant impact on household incomes and education. As most of the groundwater sources are impacted by sewage and industrial pollution in urban areas, public health impacts of groundwater use is quite high.

As per the Central Public Health Engineering and Environmental Organization (CPHEEO) norms, minimum per capita water requirement in settlements without sewerage is 70 litres per capita per day (lpcd) and it is 135 lpcd for the settlements with sewerage. A benchmarking of water utilities in India was conducted across 20 large cities of India in 2007 (ADB 2007). The average consumption per capita reported across 20 cities was 123 lpcd. Many cities had per capita consumption in the range of 70 to 90 lpcd only. On average, only 25% of the connections were metered. Average Unaccounted for water was 32% which is almost double of the CPHEEO norms (15%). The following Figure 4 presents O&M cost distribution incurred by ULBs for water supply infrastructure.

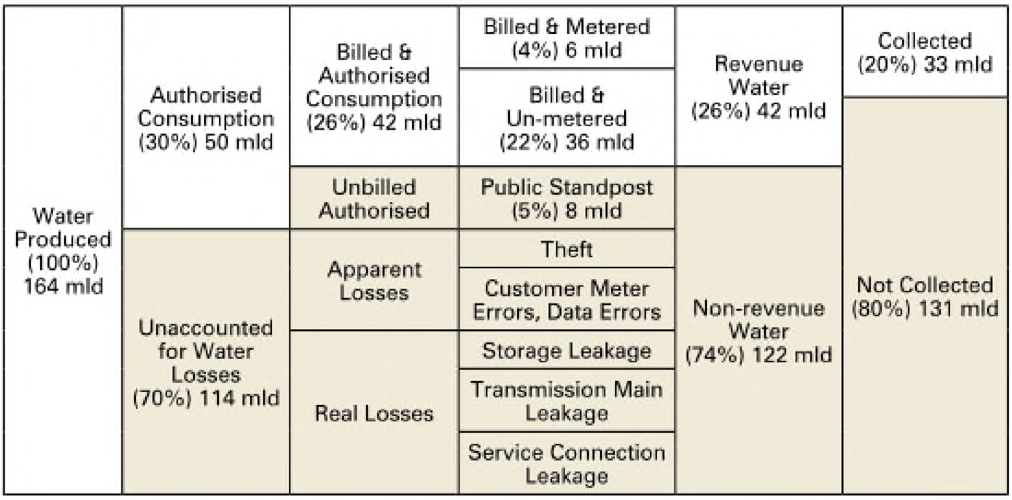
Figure 4: O&M expenditure by ULBs for water supply in important cities



Source: ADB, 2007

Energy costs form the more than half of the O&M costs across most of the cities, especially for the cities accessing water from distant source. A water balance for a typical Indian city from the Indian Infrastructure and Services report, 2011 is presented in Figure 5.

Figure 5: Water balance in typical Indian city



Source: HPEC, 2011

Losses occurring at various stages from water production stage to user end are shown. The revenue is collected from only 20% of total water produced. This seriously affects O&M of the water infrastructure by the ULBs and results in poor services.

The urban water supply system is highly inefficient both in terms of revenue collection as well as proportion of water actually produced vs. actually used. This is unfortunate considering the growing scarcity and the coping costs borne by the residents to manage water scarcity. The coping costs of water include private borewells, household storage systems and purifiers, resulting in each house or building maintaining a mini-utility. The poor end up paying many times the cost of municipal water supply tariffs for domestic use, due to lack of space and unaffordability of these coping measures. Water situation across a few major cities is summarised in the following Table 5.

Table 5: Water resource and supply situation across major cities in India

City	Rainfall (cm)	Geological Formations	Daily Water Supply (MLD)	Surface water supply (MLD)	Surface Supply (%)	Groundwater supply (MLD)	Groundwater supply (%)	Max distance from source (km)
Amritsar	39	Alluvium	171	0	0%	171	100%	0
Delhi	47	Alluvium	3,234	2,781	86%	453	14%	400
Ahmedabad	50	Alluvium	624	580	93%	44	7%	300
Faridabad	51	Alluvium	240	0	0%	240	100%	0
Rajkot	55	Consolidated	144	144	100%	0	0%	50
Indore	66	Consolidated	183	170	93%	13	7%	70
Kanpur	74	Alluvium	385	255	66%	130	34%	0
Vadodara	81	Alluvium	270	255	94%	15	6%	30
Surat	94	Alluvium	555	516	93%	39	7%	80
Itanagar	174	Consolidated	10	10	100%	0	0%	0
Mysore	216	Consolidated	187	187	100%	0	0%	15

Source: CDPs of various cities. TARU Analysis, 2013

The above data only presents part of the picture, since data on volume of groundwater extraction by households is largely unknown in most cities. For example, residents of water scarce cities like Rajkot and Indore have drilled borewells since the early 1980's and are using groundwater extensively to cope with the perpetual water scarcity. The city water supply sources of most of the cities include a mix of surface and groundwater. Some of the cities are dependent on distant sources and numbers of cities depending on distant sources are bound to grow as the demand increases due to population growth.

1.4 Poverty of Services

The core areas of most Indian cities with centralised piped water supply also suffer from intermittent supplies and quality issues. The old and decrepit distributions systems are unable to meet the demands due to densification of the city core and increases in water demand. High subsidies are major disincentives to adopt water conservation. The households are forced to to drill private borewells, build cisterns, install pumps and water filters to convert intermittent supplies to 24 x 7 supplies at the point of usage. The coping costs of installing these “mini water utilities” can costs range from few thousand up to few lakh Rupees.

The urban local bodies are often unable to extend lifeline services in fast growing cities due to the lack of funds and resource constraints. Water supply and sanitation related issues in poor and low SEC settlements are often unaddressed by most of the ULBs. Insufficient water availability, limited supply hours, stand posts and poorly built toilets, solid waste disposal problems, open drainages affect the daily life of urban poor and also increase the disease burden.

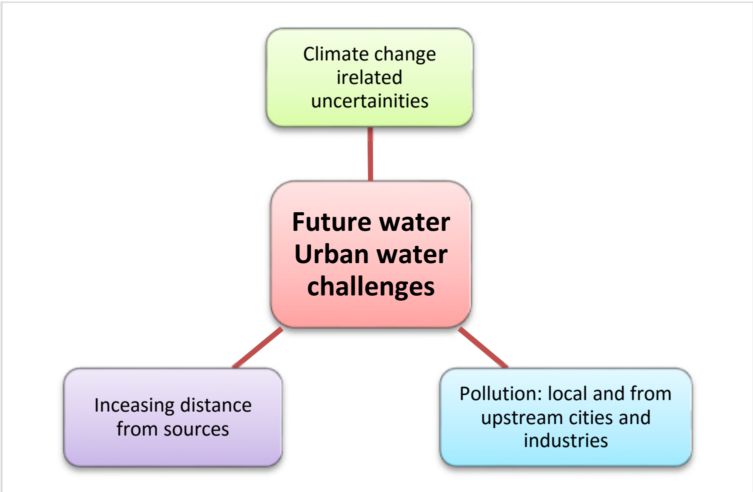
There are eight goals and 18 targets to be achieved in the Millennium Development Goals (MDG) declared by UN in the year 2000. The seventh goal is to ensure environmental sustainability. The 10^{th} target of this goal states that by year 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation will be reduced to half. The baseline year considered for monitoring the progress was 1990. In the year 1990, 34% households (rural + urban) in India did not have access to safe drinking water and thus the target was to bring it down to 17%. As per the CSO Report (2011), this target is achieved way back in the year 2007-08, but the actual the situation especially in urban areas, has improved marginally compared to rural areas. Based on the situation presented in various studies, following conclusions can be drawn regarding the urban water supply status in India:

1. About 40% population in urban areas do not get water from treated sources.
2. 25% households in urban areas use groundwater as source of water supply.
3. 75% people in urban area get drinking water in their premises.
4. 23% have to travel up to 200m away and 2% up to 500 m away from their premises to get drinking water.
5. Per capita water availability in important cities is between 70 to 90 LPCD (almost 40% less than 135 LPCD prescribed norms of CPHEEO).
6. Unaccounted for Water (UFW) losses are on an average 30% in urban areas. This seriously affects the water availability in urban areas. It should be 15% as per the CPHEEO norms.
7. The revenue collection is only 20% for total water produced. This affects the O&M of the water supply system in urban areas as well as reduced funds to expand the network and sources.
8. The poor pay higher for the water, face conflicts over water and also bear a higher disease burden.

1.5 Challenges to future water supply arrangements

Water supply and sewage disposal management in urban areas is a growing challenge due to rapid urbanization as discussed earlier. The pace of infrastructure improvement is not keeping up with the growth. There are three important concerns that will further impact future water supply in expanding urban areas.

Figure 6: Challenges to future water supply



Source: TARU, 2013

1.5.1 Importing water from distant sources

The mismatch between increasing water demand and supply in many cities across India has already become critical. Presently, most of cities in India are importing water from distant sources ranging from few kilometres to more than 100 km. Any reduction at source can lead to importing water from even more distant sources. Capital costs for accessing these more distant resources would be much higher than that for nearby sources. With increasing energy costs, O&M expenditure from distant source based systems is likely to increase. The Metropolitan city of Delhi is situated on the banks of the Yamuna, yet it gets barely 25% of its needs from the Yamuna River. The remaining supply is managed from distance sources (*Bhakra and Ramganga dams*). The situation in cities like Mumbai, Hyderabad, Chennai, Pune, Indore and Ahmedabad is similar or even worse.

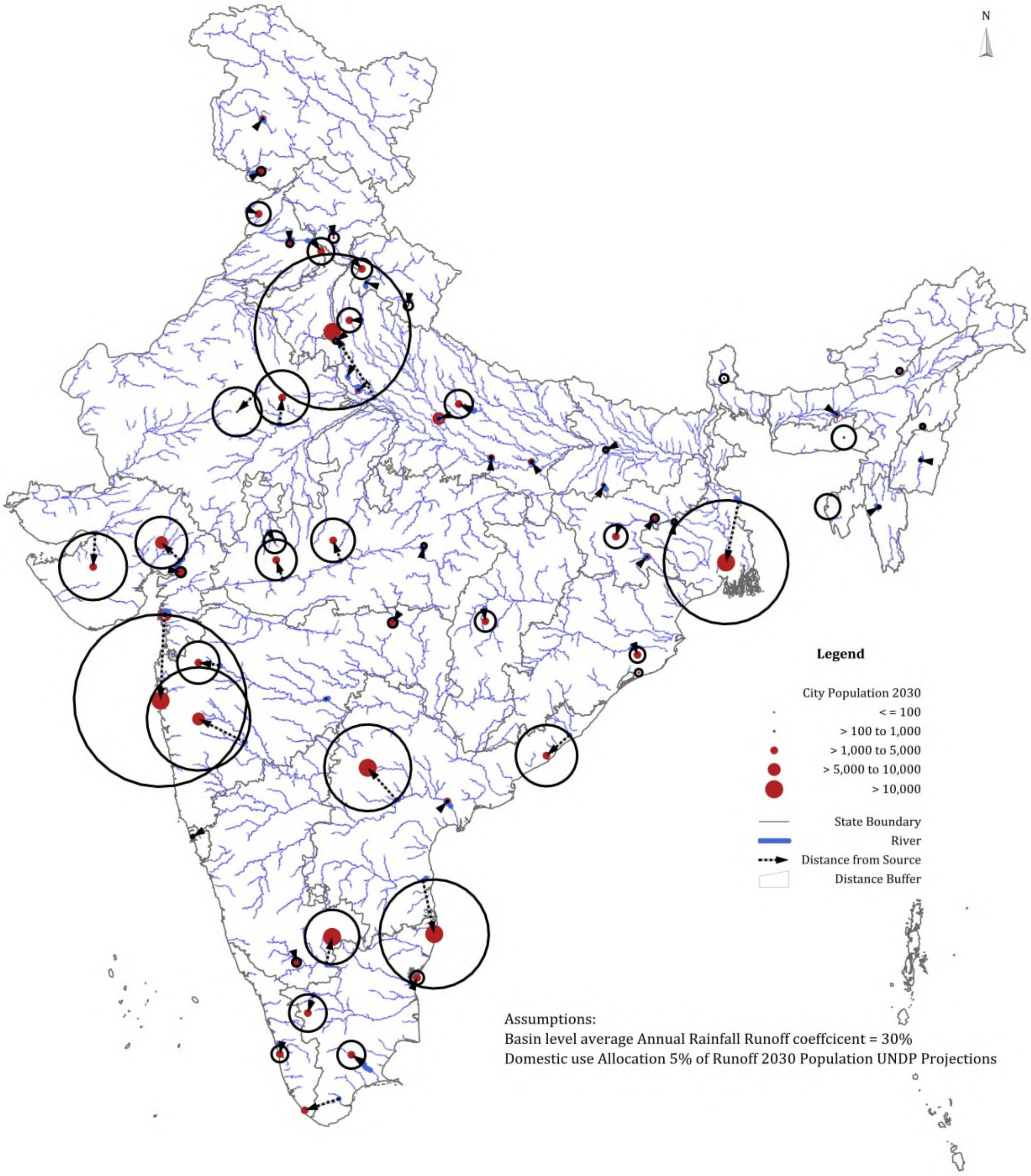
The following are the important issues related to the import of water from distant sources

1. High capital cost of infrastructure and subsequently its maintenance
2. Energy and fuel dependency for conveying water from long distances
3. Operation and maintenance
4. Conflicts and competition with existing users of distant sources

By the year 2030, the large cities in India will require around 11.5 billion cubic meters of water annually for domestic requirements (*ACCCRN Synthesis report, 2013*). Considering the present norms of CPHEEO of water supply, the cities will have to import water from distant resources (reservoirs). The following Figure 7 represents the distance of resources from which cities will have to import water for the future requirements. The radius of the circle represents the distance the city will have to cover to bring the water.

Transportation of water over long distances requires energy for pumping. The existing thermal and hydroelectric plants are already facing resource constraints (coal & water). Increased electricity generation would require additional water resources and these demands can conflict with urban water demands.

Figure 7: Nearest water sources for Indian cities to meet future water demand



Source: TARU, 2013; ACCCRN Synthesis report

1.5.2 Pollution from upstream cities and industries

In India, as per the Central Pollution Control Board (CPCB) estimates, urban waste water treatment efficiency is only 30%. The discharge of wastewater from domestic and industrial consumption pollutes the drainage system and local aquifers. With increased urbanization, water consumption and wastewater discharge is bound to increase. Industrial growth has also given rise to severe environmental pollution. About one third of the total water pollution is due to untreated effluent discharge, solid wastes and other hazardous wastes from industries. Industries generate water pollution loads which are often toxic (lead, mercury, hexavalent chromium, cyanides etc.) and varied in composition. Agriculture has become increasingly dependent on fertilizers and pesticides and irrigation return flows often contain inacceptable levels of nitrates and pesticides.

The domestic and industrial effluents discharged in rivers, ponds, lakes in the upstream area of river basin cause water pollution downstream. As most of the cities are located along rivers, the polluted raw water of cities downstream would require additional treatment. Cities like Faridabad and Agra are facing challenges of poor input water quality caused by dumping of untreated sewage by Delhi. Additionally, regular monitoring and costly treatment systems would be required to deal with sewage, pesticide and other toxic chemicals.

1.5.3 Climate change and possible impacts on city water supplies

Climate change is expected to cause increase in temperature as well as changes in precipitation pattern. Possible impacts on urban systems are presented in the following Table 6.

Table 6: Impacts of climate changes in urban areas

Climate change Prognosis	Impacts on urban areas
Extreme temperatures, Longer hot periods	Increase in the domestic water and space cooling demand due to increased temperatures and urban Heat Island (UHI) effects High evaporation losses from reservoirs Changes in vector borne disease patterns and impacts on public health
Intense rainfall with long dry spells, shifting of monsoon seasons	Reduction in numbers of rainy days and increase the drought occurrences with increase in scarcity periods causing variability in reservoir storage and resultant conflicts during droughts. Increased erosion from catchments and siltation in reservoirs affecting overall storage capacity of reservoirs affecting the water supply to cities. Risk of flooding and waterlogging conditions contaminating water supplies. Increasing risks of water borne diseases, especially during floods and scarcity periods

Source: TARU Analysis, 2012

One of the most important concerns regarding climate change is changes in precipitation pattern. Increase in high intensity events as well as droughts are expected to increase uncertainty in water storage of reservoirs resulting in need for sourcing water from more distant rivers and dams as well concentration of pollutants in existing sources during scarcity periods. As the temperature is expected to increase, the per capita water demand will also increase. The city level water demand increase especially during summer lean periods can increase pressures on existing sources. As the climate change rolls out, urban water supplies would become increasingly vulnerable, with differential impacts across regions as well as cities.

1.6 Water supply and sanitation status in poor settlements

Poor and informal settlements in urban areas face regular hardships from limited access to lifeline infrastructure services. The lifeline services for poor are mainly provided as charity and the providers lack the approach of treating them as customers (WSP, 2009). Water supplies in poor settlements are mostly in the form of stand posts and hand pumps. Community bore wells connected to common storage tanks (with few taps) are common. Piped supply from municipal sources is mostly found only in old and established poor settlements in core urban areas. For many poor settlements, water supply is also arranged from external sources i.e. government water tankers. Electricity power cuts & borewell pump failures are common in poor settlements resulting in frequent water scarcity, in addition to the drying up of borewells during summers. The Table 7 presents the water supply status in slum settlements across India. The data presented shows comparative improvement during five years between 2002 and 2008-09.

Table 7: Percentage of slums with lifeline infrastructure during preceding five years

Facility	2002		2008-09	
	Notified	Non-notified	Notified	Non-notified
Water supply	48	32	49	30
Latrine	50	33	34	24
Drainage	47	23	40	28
Sewerage	24	6	23	11
Garbage disposal	41	15	42	26

Source: CSO , 2011

As per surveys conducted in year 2008-09, about 20% (9,800) of the slums did not have formal water supply arrangements. If 200 households with 6 family members each are assumed in an average slum, then approximately 12 million people residing in the slums do not have access to piped water supply from city water systems.

1.7 City level Water management

Availability of perennial water in sufficient quantities was necessary for the formation of large settlements, which could grow into cities. As climatic, physiographic as well as geological conditions result in diverse water endowment contexts, a variety of technologies evolved to meet water demands across cities. Rainwater harvesting, canals, tanks and wells were common technologies used in the past. Elaborate rules of water use and management practices were also developed. Most of the old systems depended on gravity fed aqueducts and wells.

Urban hydraulic systems are dated at a later stage, in the Bronze Age (ca. 2,800–1,100 BC). There are several astonishing examples of urban water systems from about the mid-third millennium BC. Mohenjo-Daro, a major urban centre of the Indus Civilization, developed a sophisticated system for *water supply and sewage. Water came from more than 700 wells and supplied not only domestic demands but also a system of private baths and a Great Bath for public use (Jansen, 1989).*

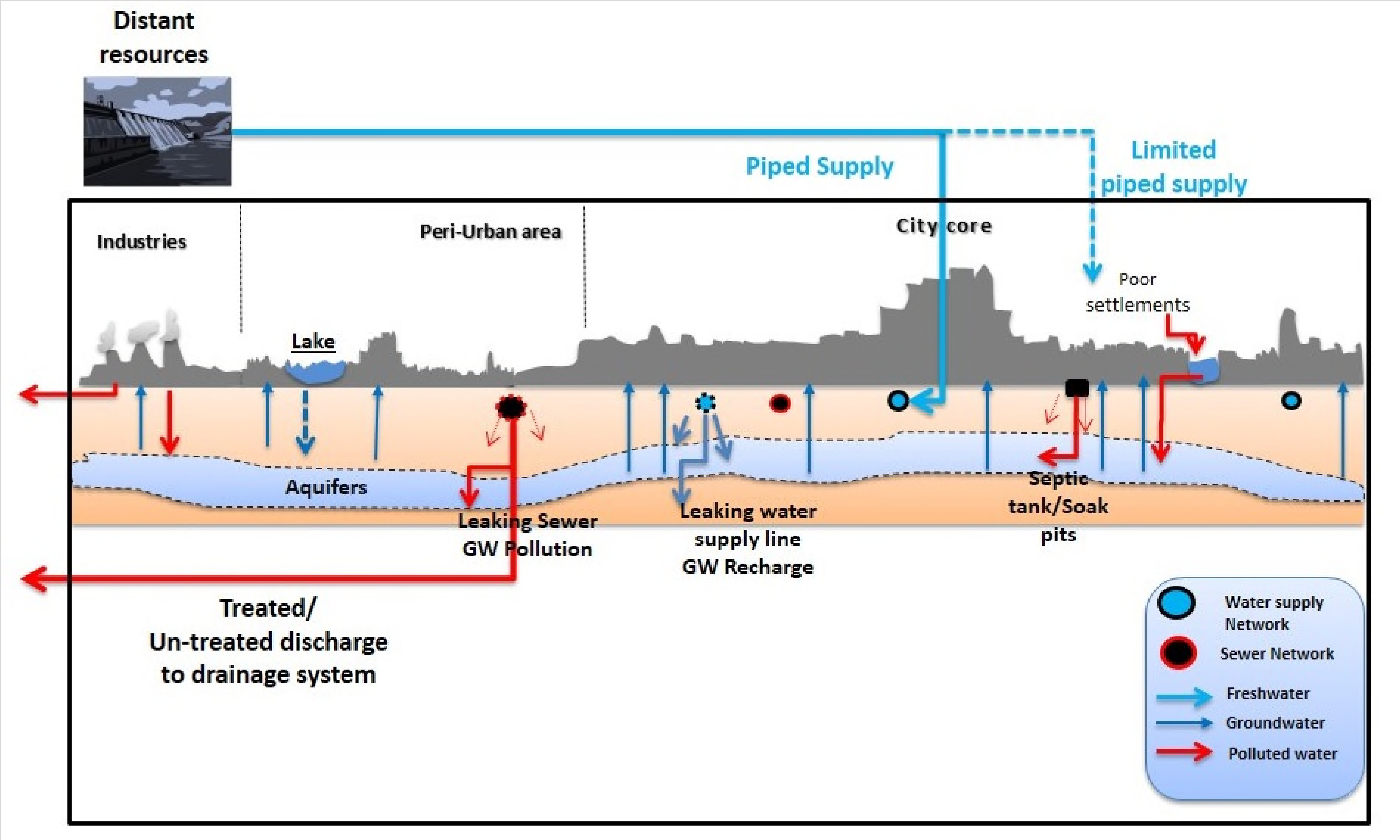
In the early part of the last Century, pump and electricity technologies became popular and large scale transport of water from distant sources was made possible. Urban local bodies took the responsibility of providing water to the citizens and they commissioned centralised water supply systems, managed the networks and collected water user charges. With large centralised water supply systems coming up, local resources could be ignored and often lakes and other water bodies were encroached or filled up to accommodate expansion of cities. Now the city water supplies consist of centralised infrastructure including pumping stations, treatments plants, conveyance pipelines and distribution networks. As cities continued to expand, these centralised systems could not be managed efficiently as the need for high subsidies and other management issues cropped up. The cities often could not augment their sources and also were unable to expand the water networks in urban sprawls.

Coverage of infrastructure as well as services shows very high diversity in cities across the developing countries. In core areas, piped water supply is mostly available, but often the densification has resulted in insufficient capacity of the existing networks, while it is difficult to augment the supply due to high costs of laying additional facilities over already dense settlements. The poor and informal settlements were often excluded from centralised supply due to barriers of lack of tenure, location and other reasons.

The urban water supplies are highly subsidised and cross subsidisation of domestic water supply is done through high tariff on commercial and industrial sectors. Since the consumption of the domestic sector is often many times the other sectors, the cross subsidisation requires very high tariffs on other sectors. Many of the cities have industrial estates lying outside the city limits, which limits the possibility of cross subsidisation. As a result, ULBs are often unable to recover the O&M costs resulting in deteriorating infrastructure, which in turn leads to more leakage losses.

As the centralised supplies are unable to provide sufficient water, households often install a variety of coping systems including groundwater based systems. At the sub-city levels, the drainage conditions, and geological inhomogeneity controls the aquifer conditions. The groundwater situation varies widely across the city, even in alluvial and coastal areas. While some parts have good aquifers, others may not have them or aquifers may be overexploited or have been polluted from leaking sewage. The fast growing urban sprawls outside the city limits depend mostly on groundwater through private investments. The Figure 8 presents the interaction between water supplies, sewerage and groundwater in a city.

Figure 8: Water supply arrangements in growing cities

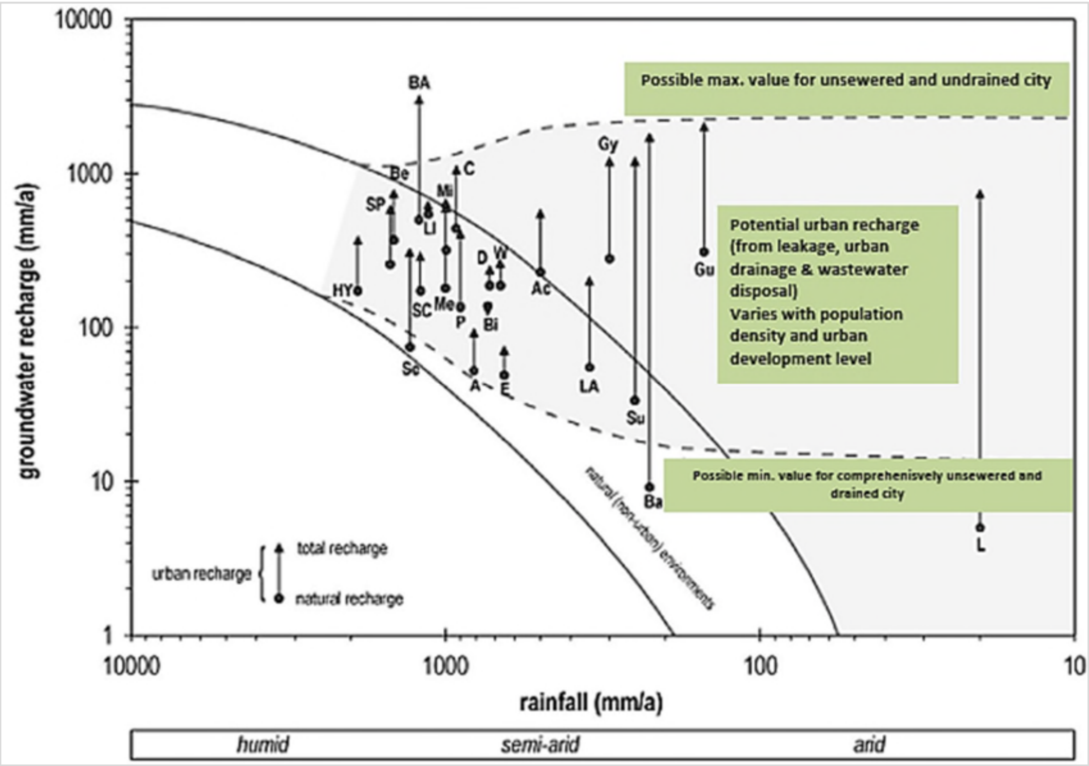


Source: TARU, 2013

While the city utilities focus on piped water supply and sewerage, local sources like streams, lakes and groundwater resources are often ignored while planning the city and its water supply systems. As a result, the aquifers get polluted or overexploited to meet increasing demands. In many cities with permeable soils, the urban groundwater recharge may be many times the natural recharge due to year round leakage from water supply and sewerage networks. This results in rise of groundwater in the core areas with centralised water supply and sewerage network. In peripheral areas, dependant on groundwater, decline of water table is often observed.

The government agencies conducting monitoring of groundwater have no de facto powers to regulate the groundwater usage or control pollution. As the city grows, the groundwater quality degrades, especially in the core. The following Figure 9 presents the urban recharge in different climatic and sewerage conditions.

Figure 9: Urban groundwater recharge in different rainfall and sewerage conditions



Source: Foster et al. 1994

Centralised planning and management results in losing valuable local resources that can potentially be used as an emergency source in case of failure of centralised supplies. The status and issues related to urban water supply in various zones of the city is presented in the following Table 8.

Table 8: Water related issues in various parts of the city		
Peri-urban area	**Main City Area**	**Poor Settlements**
Groundwater is primary source, but preferentially captured by elites by deep borewells, while poor suffer from drying of shallow wells Mostly privately managed water infrastructure High cost, seasonal scarcity, reducing quality Surface water bodies degrading from dumping of sewage and solid waste leading to reduced recharge of aquifers	Limited coverage and intermittent water supply Ageing infrastructure of water supply and sewerage amidst increasing densification of the care city Unaccounted For Water (UFW) losses are high Elite capture of centralised water supply Poor revenue collection affecting O&M of infrastructure	Located mostly in risk prone areas like along stream beds, flood plains, with floods affecting water sources and quality Inadequate sewage and solid waste disposal increasing health risk Lack of land tenure is often a barrier to access piped water supply and high dependence common sources leading to conflicts Lack of sufficient storage facility at household level Loss of time leading to decrease in incomes

Source: TARU, 2013

While the ULBs are unable to provide sufficient water, (especially in the poor as well as peri-urban areas), mechanisms for community level management have not evolved except for in a few newly built large townships and colonies in peripheral areas. Even in these areas, source sustainability issue is not addressed. For example, real estate developers build houses based on groundwater supply, create septic tanks for sewage disposal and sell the houses. The buyers then face the water scarcity and pollution impacts afterwards. Since these colonies were built without adequate understanding of the resource context, the groundwater was a quick fix solution, which led to overexploitation after the houses were sold to the users and the responsibility of management was transferred to the community. The communities then have only the option of deepening the bore wells. Understanding the local resource context as well as willingness of community is necessary to design local interventions. Innovative solutions would include use of multiple resources like rainwater, groundwater as well as reuse of treated waste water. Lack of knowledge and technical support as well as poor community cohesion are some of the challenges preventing sustainable management of water.

In poor settlements which have a piped water supply, elite capture at the head end of the pipelines often creates scarcity. Many new informal settlements suffering from water scarcity are provided with community bore wells, which is often contaminated or has brackish water. With new technologies for water treatment coming up, local polluted resources can be used better through filtration systems. The following chapter provides a framework for managing urban water through decentralised management of local resources.

Urban water systems work on economies of scale and efficiency. Centralised water supply systems should typically provide economies of scale and ensure water use efficiency. Unfortunately, these systems are unable to achieve economies of scale due to system losses. The efficiency of the system has also reduced due to lack of maintenance.

This has caused snowballing of impacts on users through wasted time to collect water as well as additional coping investments by households, industries and services sector. Figure 10 represents important urban water issues.

Figure 10: Important city level water Issues

Source: TARU, 2013

1.7.1 Water availability

Insufficient per capita water availability is the most common issue in urban areas. Limited coverage and supply duration (few minutes per day to alternate day) and reduced availability during summers are common problems in most cities. Supply constraints are amplified further by high conveyance losses through aging infrastructure and also with water theft (high UFW). Since the piped water supply systems are unable to meet demands, groundwater is used by those who can afford it, especially in peripheral areas. Also, the ULBs have installed bore well based systems in informal settlements where they are unable to provide water connections. Extensive groundwater use has led to overexploitation, especially in hard rock areas, which further amplifies scarcity, especially during summers. Seasonal scarcities often catalyze formal and informal water markets (e.g.Tanker suppliers) and they often are able to charge high 'scarcity' prices. These informal systems (tankers) often provide contaminated water or even tap municipal supplies.

1.7.2 Increasing costs

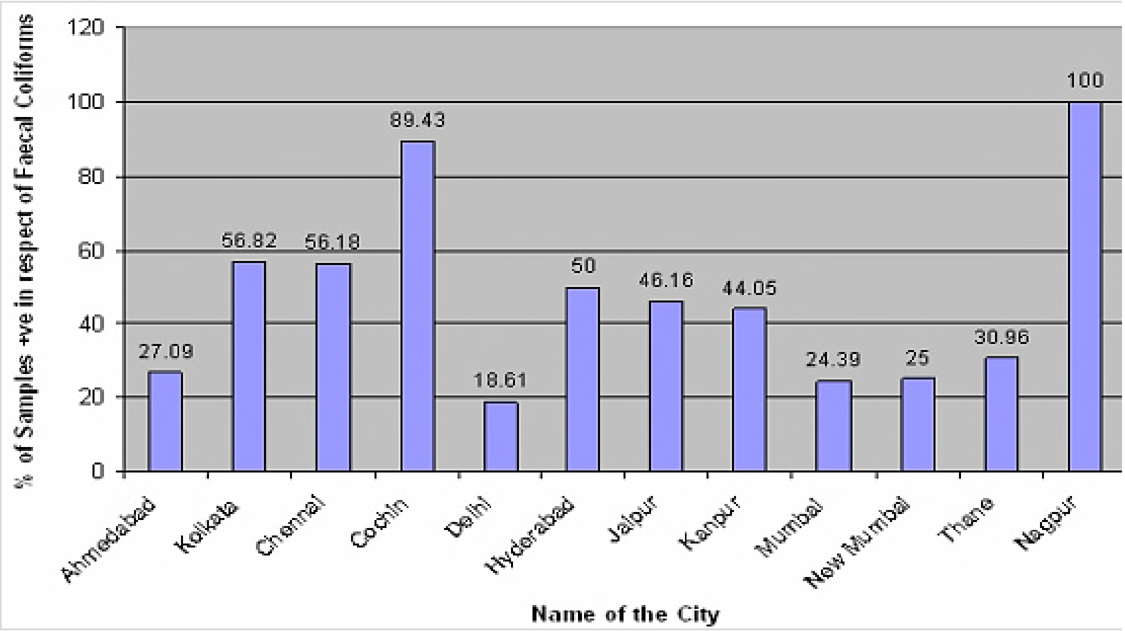
While the households connected to piped network are highly subsidised (often up to 90%), the groundwater users have to invest on drilling and pumps and also pay for electricity and maintenance. The poor pay an even higher price since they do not have access to piped water supply as well have limited storage. Higher costs are incurred by consumers of private water supplies (tanker) during times of scarcity.

1.7.3 Quality

The pipeline network is old, especially in the older parts of the city. The network requires continuous repair and maintenance. In many areas, sewage and drinking water pipelines are laid next to each other and leakage from sewers into water supply networks is quite common, especially in case of networks with intermittent supply. Leaking sewers also contaminate the aquifers by infiltration in sandy soils. Poorly constructed bore wells (without platforms and clay grouting) and lack of drainage cause direct leakage of contaminated water into aquifers without filtration by soils. As a result, both piped water as well as groundwater is contaminated in most cities.

The following Figure 11 shows quality status of water supplied in 12 important cities of India. Percentages of water samples showing faecal coliforms indicate that poor water quality is an important concern in urban areas.

Figure 11 Faecal coliform contamination in Municipal water in Indian cities



Source: SIAES, Undated

The utilities resort to excessive chlorination to deal with post treatment contamination. While middle and upper SEC households install a variety of filtration devices; the poor, who neither have access to piped water supply nor can afford filtration devices, are forced to drink contaminated water. Water related diseases can be transmitted by various routes. Following Table 9 shows some examples of water related diseases with their groups. It indicates that Diarrhoea, Dysenteries, Typhoid fever; Scabies and Trachoma are water borne diseases, which are caused by pathogens present in drinking water.

Table 9: Classification of water related diseases

Transmission Route	Description	Disease Group	Examples
Water-borne	The pathogen is in water, which is ingested	Feco-oral	Diarrhea, Dysenteries, Typhoid fever, Scabies, Trachoma
Water-washed **(or water scarce)**	Person-to-person transmission because of a lack of water for hygiene.	Skin and eye infections	
Water-based	Transmission via an aquatic intermediate host (e.g., snail)	Water-based	Schistosomiasis, Guinea worm
Water-related insect vector	Transmission by insects, which breed in water or bite near water.	Water-related insect vector	Dengue, Malaria, Trypanosomiasis

Source: SIAES, Undated

1.8 Impacts of poor water quality on poor

The poor and informal settlements without access to formal water supply bear the brunt of water scarcities due to variety of reasons. Firstly they have to buy water from informal water markets and often at exorbitant costs due to retail prices per bucket or bottles. Secondly, since they have insufficient storage capacity so they have to collect water frequently the often face conflicts over water. Thirdly, since the water is often contaminated, they face higher disease burden.

Number of diseases causing morbidity and mortality are high in urban slums and are attributed to living conditions and poor drinking water supply. Diarrhoeal diseases, Cholera, Shigellosis, Escherichia coli diarrhea, Poliomyelitis, Typhoid, waterborne Viral hepatitis etc. are common in the slums. Of these, diarrhoeal diseases alone cause more than 0.6 million deaths annually. Study has shown that in slum areas of major cities diarrheal incidence as high as 10.5 episodes per child per year occur on regular basis (SIAES, Undated)

These challenges lead to higher pay-outs for water, lost opportunities to earn and study as well as higher disease burden. Important barriers for poor in urban areas to access water and sanitation facilities are:-

1. Many of the poor settlements are located outside the city limits
2. Number of such new settlements are growing
3. Legal status of poor settlements varies. While some of the settlings are notified slums, others are not recognised by the ULBs.
4. Many residents do not own the land or buildings and therefore they cannot access water and electricity supplies due to tenure issues

Many slum dwellers do petty business that requires water (e.g. food stalls, ice-cream shop etc.). In case of the non-availability of the water, they are forced to purchase it from private suppliers (tankers) or they have to rely in nearby factories or neighbourhood colonies. Buying water or arranging it from outside sources directly impacts livelihood of poor and affects their livelihoods. Since many upper SECs buy food sold by the poor through hand carts, the disease burden of other SECs also gets affected by the water quality issues of the poor.

1.9 Enabling environment for decentralised water management

The water scarcity and groundwater overexploitation in cities have prompted several regulations to control groundwater use as well as making rainwater harvesting compulsory for large urban development projects in many cities. Indore was the first city to enact rainwater harvesting related rules for urban areas. To achieve city level impacts, it is necessary to promote large scale adoption of these measures as well as easily accessible technical support cells and monitoring of groundwater depth and quality at regular intervals. Groundwater authorities have also been created, but they are unable to regulate the groundwater usage mainly due to capacity constraints. A full and regularly updated database of groundwater structures as well as estimation of groundwater extraction is necessary at central level and monitoring information and it should be made accessible to the public to create awareness and to self- regulate the water use.

Similarly, decentralised sewage treatment would require land use and water usage regulations to enable construction of underground STPs in gardens and public spaces and also restriction of municipal water for gardening purposes. Since there are many taboos associated with sewage, this would mean regular maintenance of the STPs. To provide such services, public private partnerships would be necessary as well as availability of trained technicians. STP maintenance has to evolve as a service sector and can potentially create business opportunities.

Conjunctive Water Management (CWM) Approach

2 Conjunctive Water Management (CWM) approach

This chapter describes the Conjunctive water management (CWM) as well as Demand focussed end use approach (DEFENDUS) specifically in context of Community level management of water. The next section describes community level assessment of resources, infrastructure as well as social and affordability issues at household to settlement levels. Tools and methods for the analysis as well as few examples are provided. Implementation process is also explained along with risks and ways to manage risks.

The centralised single-source single-quality water supply systems have ignored the actual quality requirement of different end uses. A significant proportion of water demand can be met by lower qualities of water (e.g. recycled waste water for gardening), while it is currently met by high quality of water.

Sewage is transported to the large scale sewage treatment plants, mostly located at the periphery of the city, while demand for treated waste water for low end uses is mostly within the city. Except for preventing pollution downstream, these plants are not useful or economical due to large energy requirements. Even in cities importing water from large distances incurring huge energy costs, the waste water recycling is also centralised and often not working optimally due to energy and cost constraints.

The centralised water supply and sewage treatment systems are based on the premise that they are economical and easy to manage, even when the ULBs are unable to efficiently manage it. With drainage, sewerage and water supply managed as separate entities, the inter-linkages are ignored in planning, design and management of these systems. The paradigm of large centralised capital works focussed augmentation ignores the following basic facts:

- Water can be best managed at multiple scales to achieve efficiency as well as to build resilience
- It is often cheaper to reduce UFW than spending for conveying water from distant sources
- Rainwater as well as groundwater can used to supplement the other sources and can provide resilience to the centralised water supply systems
- Treated waste water is a resource which is often cheaper to use for end uses like gardening which require low quality. Since demand for treated waste water for such low end uses exists across the city, source diversification can be done at decentralised levels, near the place of demand
- Integrated water management framework is necessary in urban development planning, with due focus on conservation, waste reduction and conservation of drainage systems and water bodies
- Incentives, technical support, monitoring, regulations and IEC are necessary to create an enabling environment to encourage communities to adopt decentralised options.

Both demands as well as supply side interventions are necessary to sustainably manage water in urban areas. These measures should address issues like water security, resilience under slow and rapid changes, efficiency as well as other indirect issues like health and wellbeing of citizens.

2.1 Supply side approaches: Conjunctive water management

Conjunctive water management (CWM) can be described as optimal use of multiple sources including local and distant sources, rain water, surface water, groundwater and treated waste water for meeting various types of water demands. Diversification of sources increases the resilience of the water supply system by providing options to meet emergencies or energy and cost shocks on the system. An intelligent combination of multiple sources is necessary, depending on the seasonality of the resources, capacity, cost of energy and other factors. These sources can be managed at various scales ranging from households to colonies or sub-districts, depending on resource endowments characteristics.

Three main issues related to urban water management namely seasonality, costs and quality need to be understood for applying the conjunctive water management framework. Additionally, the optimal scale of intervention needs to be worked out.

In the urban context, both existing resources as well as waste recycling approaches can be used to increase supplies. The scale of interventions required to manage each resource varies as well as the associated costs and benefits. While some of the resources may not seem attractive when compared with highly subsidised piped water or on the basis of a purely financial cost benefit analysis, they can reduce the time wasted for dealing with scarcity, making these approaches socially and economically viable. Also they improve resilience of the system. Some of the resources and their characteristics are presented in the following Table 10.

Table 10: Important characteristics of different urban water resources

Resource	Seasonality	Cost	Quality	Remarks
Rainwater	Highly seasonal, depends on rainfall averages and pattern	Storage costs across seasons high. Can be used for Groundwater recharge	Excellent	Rainfall occurs within few hundred hours during monsoon periods. High annual variation in semiarid and arid regions. Prevention of mixing with pollutants critical. Best managed at building levels.
Groundwater	Perennial, if managed within recharge limits	Depends on depth, drilling and energy costs	Variable, can be polluted if sewerage is not managed well	Finite resource depends on recharge, High lateral inhomogeneity in distribution of aquifers in hard rock terrains. Can be managed at various scales, but close monitoring necessary to ensure sustainability and quality.

Table 10: Important characteristics of different urban water resources				
Resource	**Seasonality**	**Cost**	**Quality**	**Remarks**
Treated wastewater	Perennial source in urban areas	Depends on extent of treatment, can be cheaper than distant sources	Can be used for low end uses, May not be socially acceptable for drinking, washing etc.	May not be viable if industrial pollutants are mixed. Best managed at community levels. Can reduce load on sewerage system.

Source: TARU Analysis

Depending on the context, these resources can be used at various scales ranging from households to communities. A strategy of combining different resources can meet significant proportion of water demand of the settlements.

2.2 Demand side approaches: Demand Focussed End Use (DEFENDUS)

The centralised supplies provide treated water (matching drinking water quality standards) for meeting all end uses. Most of the water used in households and other uses actually require much lower quality of water only. Various qualities of raw water as per Central pollution control Board are presented below to explain the possibility of matching the water quality as per the demand.

Table 11: Designated use of raw water with quality

Designated-Best-Use	Class of water	Quality
Drinking water source without conventional treatment but after disinfection	A	Total Coliforms Organism MPN/100ml shall be 50 or less pH between 6.5 and 8.5 Dissolved Oxygen 6mg/l or more Biochemical Oxygen Demand 5 days 20°C 2mg/l or less
Outdoor bathing (Organized)	B	Total Coliforms Organism MPN/100ml shall be 500 or less pH between 6.5 and 8.5 Dissolved Oxygen 5mg/l or more Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	Total Coliforms Organism MPN/100ml shall be 5000 or less pH between 6 to 9 Dissolved Oxygen 4mg/l or more Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Propagation of Wild life and Fisheries	D	pH between 6.5 to 8.5 Dissolved Oxygen 4mg/l or more Free Ammonia (as N) 1.2 mg/l or less

Table 11: Designated use of raw water with quality		
Designated-Best-Use	**Class of water**	**Quality**
Irrigation, Industrial Cooling, Controlled Waste disposal	E	pH between 6.0 to 8.5 Electrical Conductivity at 25°C micro mhos/cm Max.2250 Sodium absorption Ratio Max. 26 Boron Max. 2mg/l
	Below-E	Not Meeting A, B, C, D & E Criteria

Source: CPCB website

Among the domestic uses, only the water used for drinking and use in the kitchen needs to be of high quality, while other uses like washing, bathing, flushing and gardening do not need high quality of water. Treatment of large quantities of water to drinking water quality is inefficient use of capital, energy, chemicals and staff costs.

The Demand Focused End Use (DEFENDUS) approach offers a framework for analysing the demand and resources based on quality criteria and matching the demands with appropriate quality of water available.

2.3 Quality requirements of domestic water demand

Domestic water is used for a variety of purposes ranging from drinking water requiring high quality of water, to gardening requiring the lowest quality of water. The Table 12 presents daily domestic water requirements as per CPHEEO norms for Indian conditions.

Table 12: Daily domestic water design parameters and quality in various activities

Activity	Water requirements (LPCD) CPHEEO norms		Water Quality Class CPCB norms	Remarks
	With sewer	Without sewer		
Drinking & Cooking	7	7	A	High quality water
Bathing	20	15	B	Full body contact quality
Cloth and utensils washing	30	30	B	Soft water that does not leave soap after washing
Flushing, floor cleaning and vehicle cleaning	40	10	C/D	Recycled water can be used
Gardening	23	-	E	Mostly in high SEC. Recycled water can be used
Total	135	70		

Source: CPHEEO website

Drinking and cooking activities require high quality water. Washing utensils, laundry and bathing water should be soft, does not leave soap after washing and also does not have bacteriological contamination. Bathing requires water satisfying full body contact quality. Even though treated waste water can be potentially used for bathing and washing (after UV treatment), it is socially not acceptable.

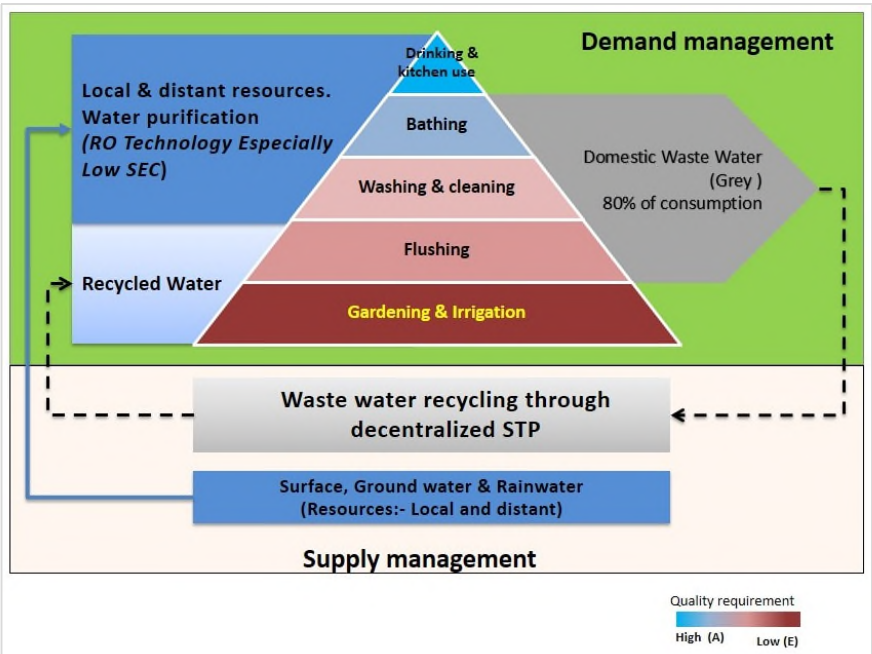
Flushing and floor and vehicle cleaning do not require high quality water. In India, a small portion of the upper SECs only maintain gardens in their premises and in open spaces requiring watering. Gardening/irrigation activity does not require high water quality in terms of bacteriological contamination. Treated waste water can be used for meeting these low end needs. Treated waste water also can be effectively used to indirectly recharge the groundwater through soil-aquifer treatment technologies.

Important benefits of the CWM and DEFNDUS approach are:

1. Control and protection of local resources by the communities (traditional open wells, ponds, lakes)
2. Back-up supplies in case of droughts/distant sources failure
3. Lower costs when taking into consideration true costs of distant sources
4. Adequate and appropriate quality water availability to meet demands.

This approach is advantageous for both suppliers (ULBs) as well as consumers (communities, industries etc.). It creates opportunity for usage of local water sources like traditional open wells, lakes, ponds. By regularizing their usage to meet daily low end usage requirements, dependency on distant resources can be significantly reduced. The t reduced demand on water can significantly reduce the subsidy burden on the ULBs.

Figure 12: Decentralised Demand and supply management



Source: TARU, 2013

As represented above, only 10 litres of high quality water is required in drinking and cooking activities. A large volume of lower quality water is required to meet demands for bathing washing and flushing etc. The centralized systems in India have so far focused on providing 135 LPCD of water of drinking water quality, the costs of production are quite high and the utilities are unable to meet demands also. Separating low end uses can significantly reduce the wastage of drinking quality water currently being used for all categories of usage.

Following Table 13 provides an overview of daily water requirements and estimates for waste water generated with consumption from various size settlements. The estimates for water requirements are made considering a household size of 5.Waste water estimates are estimated considering 80% waste from the consumption.

Table 13: Daily Waste water generation and Demand for low end use (cu.m/day)

No. of HHs	Areas with sewer network			Areas without sewer network		
	Water demand	Potential for treated waste water	Demand for Low end use	Water demand	Potential for treated waste water	Demand for Low end use
100	68	41	32	35	17	5
250	169	101	79	88	42	13
500	338	203	158	175	84	25
1,000	675	405	315	350	168	50

Source: TARU, 2013

The above table shows that decentralized waste water treatment can meet all the low end uses even if only 75% of the waste water can be recovered in case of areas with sewers and 60% in areas without sewer networks. It would reduce the load on the centralised waste water treatment as well as the need for higher diameter sewer networks to convey all the sewage generated.

Design and Implementation of Decentralised Options

3 Design and implementation of decentralised options

This chapter explains collection and analysis of data required to identify suitable options, participatory selection of technologies and implementation of the interventions selected. The data collection process suggested is only indicative and context specific modifications may be necessary to suit different resource, infrastructure and socio-economic contexts. The process of selection may be adapted to suit local situations. The community engagement process and interventions section explains the process and also explains how to avoid risks. This chapter is to serve only as a guide and the implementers should preferably adapt the process to specific situations.

Decentralised options can only be managed by user community or individual households or at multi-storeyed apartment block levels. The ULBs can create enabling environments through technology support, monitoring and regulation, but managing multitudes of decentralised systems cannot be effectively done at city scales. While some of the technologies are best managed at building levels, others are best managed at settlement levels. The following process is suggested for designing and implementing Decentralised water management systems.

Stage 1 Community context analysis

Analyses of resources, demand & supply estimates as well as community situations are done at this stage. This stage provides the input for a design brief and for choosing technology options. The analysis includes:

- Resource situation and characteristics
- Current water supply, sewerage and soil waste arrangements,
- Current and future demands
- Community cohesion and capacities
- Willingness to engage

Several focussed studies would be necessary to understand the above issues at the settlement levels.

Stage 2: Selection of Technology options

Based on the issues identified, a suite of technologies can be shortlisted and discussed with the communities. Awareness generation through IEC activities is an essential part of this stage. The community should be having the cost and management implications each of the technologies as well as benefits should be known to the community.

At the end of this stage suitable technologies are shortlisted along with possible management mechanisms and the roles of different stakeholders should be known to the community

Stage 3: Implementation

This is the most critical stage. The main activities are:

- Role definition and Agreements between stakeholders, contractors etc.

- Community level management system
- Operation and maintenance mechanisms including
    - Annual maintenance contracts
    - Training and capacity building of staff
- Financial system including user tariff fixation, monthly budgets etc.
- Monitoring systems
- Exit strategy

The implementation stage should be taken up only after binding agreements are drawn out. The role of each one of the stakeholders should be clear to all parties. As far as possible, communities should be involved in the contracting and management of the interventions.

It is always desirable that the communities take up the management right from the beginning. A community level committee is best suited for this purpose and many of the ground level issues and conflicts can be solved by this committee. While a leader is preferred who can take initiatives, care should be taken to avoid undermining the group by takeover by the leaders.

Some of the interventions would require regular operation and maintenance. Preventive maintenance is a weak spot, which can significantly reduce the life of the plant as well as increase downtime. It is a challenge in developing countries to ensure that regular preventive maintenance is done. Training and capacity building and of staff in regular operation and maintenance mechanisms should be in place when the system is ready. An operating manual that is easily understandable and accessible by the staff is a must. Also, clearly defined standard operating procedures as well as performance and maintenance logs are necessary and staff must be trained to use these on regular basis.

In some of the interventions requiring advanced materials and technical support, Annual maintenance contracts and availability of regular consumables should be ensured. While operation and routine maintenance can be done by the communities, it is preferable that the more complex maintenance is done through Annual maintenance contracts.

Many projects would require regular collection of user fees as well as payments to the contractors, staff etc. A functioning financial system has to be developed for these and the staff should be trained to handle finances. Bank accounts are preferred and handling of loose cash should be avoided.

A good mechanism to monitor physical as well as financial performance should be in place. While some of the functions can be done by the Community committee, external inputs would be essential for monitoring water quality and performance levels of the systems as well as adherence to preventive maintenance

An exit strategy should be worked out at this stage so that the role of the external implementation agency can be slowly withdrawn over the project period, with the community taking the responsibility as the implementation agency withdraws their roles. The following section elaborates these steps in detail.

3.1 Community assessment to identify water related issues

As the scale changes water & sanitation issues change from households to communities and can be attributed to different reasons. In order to develop options, it is essential to first assess the current context as well as emerging issues over time. Following issues need to be explored to design briefs for developing options. The assessment of community can be done through Community Context Analysis (CCA) exercises. The community context analysis explores the resources, demand and supply situation as well as socio economic contexts of the community

A mix of tools ranging from questionnaires, participatory GIS, focus group discussions and World café can be used for collecting the information. These tools need to be adapted to suit the community's capacity to provide information and should be augments by observation and scientific studies. It also provides to opportunity to engage with the community at household to settlement levels.

3.1.1 Resource analysis

The communities use a variety of resources including water bodies, rivers and bore wells. Also they may be supplementing local sources with transport of water from external sources. Resource analysis involves study of resources, their characteristics including seasonality, costs and quality. It also should analyse the linkages between different sources including urban recharge from streams and septic tanks etc. While some of these information may be collected from local sources (numbers of borewells, depth of water table), other information collection and analysis may require support from technical departments. Most of the cities have offices of groundwater departments and academic institutions specialised in this field. They can be involved to analyse such information. Important information includes:

- Rainfall patterns, variability
- Physiography, Drainage system and water bodies and their use, if any
- Soil characteristics, especially percolation rates
- Water logging
- Aquifers and extraction rates

Geographical (topography, slope), meteorological (rainfall, temperature) and geological (rock & soil types, their constituents) characters of the region determines the water resource distribution across space and seasons. While detailed studies may require expert support, a brief introduction of some vital information necessary is presented.

3.1.2 Climate (Rainfall/Temperature)

Amount and distribution of rainfall controls the distribution of water resources across seasons. In areas where rainfall is distributed well over seasons, direct rainwater harvesting is a good option, especially where buildings have conventional roofs of adequate size. In slums and informal settlements with small and diverse roofs, roof water harvesting may not be feasible.

3.1.3 Physiography

The regional topography/terrain controls the surface runoff (flow of water on ground) and infiltration factors. Slope of the area controls the waterlogging or fast surface runoff. If the surface runoff is high, than the chances of recharge or to store the water reduces. In urban environments built up areas intercept the rainfall. As built up surfaces are generally more impervious and the proportion of rainfall to runoff increases and it is an opportunity if the rainwater is harvested in situ or can create additional runoff and change the intensity of flooding, if not stored. Urban development often modifies the drainage by narrowing the stream width, which also can increase flood intensities.

3.1.4 Soils and vegetation

There are two main types of soils. Sandy soils allow higher percolations; while clayey soils have low permeability and can cause prolonged water logging in flat terrains. Types of vegetative cover act as a sponge and also allow slow percolation by intercepting and delaying runoff to some extent. The thickness of soil cover determines the extent of storage within the soils.

3.1.5 Geology

Three broad rock categories i.e. Granites, Basalts and Soft rocks (sedimentary) have different aquifer characteristics. Granites and associate rocks have no primary porosity and the almost all aquifers are due to secondary porosity due to deformation. The basaltic rocks have formed due to solidification of molten lava and occur as multiple flows stacked one over next. Good aquifers are found in between layers of basalts as well as within the layers due to contraction cracks while solidification. Black cotton soils are formed by weathering of basalts, and they have high clay content and also swell and shrink depending on water content. These soils usually have low percolation capacity and prone to waterlogging. Recharge rate is quite low.

Sedimentary rocks generally have both good aquifers as in case of porous sandstones or act as barriers to water flow as in case of shale. Unconsolidated sediments include alluvium or clay found along the flood plains. The alluvium has high porosity and has good aquifers. The depth and horizontal extent of the alluvium controls the storage of alluvial aquifers.

Following Table 14 presents set of generalised climatic, physical, geological and soil situations sorted according to best to worst groundwater potentials. The category ‘A’ is most favourable conditions for aquifers whereas ‘C’ indicates adverse conditions.

Table 14: Hydro-geological conditions and groundwater availability

Category	Climate	Terrain	Geology	Soil Cover	Soil conditions
A	Humid	Valley/Flat	Alluvium / Soft rocks	Deep	Sand
B	Semi-Arid	Plateau/ Flat	Weathered Basalts	Medium	Sand/Clay
C	Arid	Hilly	Granites	Shallow	Clay / Black Cotton

Source: TARU, 2013

3.1.6 Water quality

Most of the peninsular rivers are seasonal and river flow is mostly from direct runoff from the rains. Only the river flow during the late monsoon season consists of some of the water percolated into soils. Most of the surface water is captured in dams and then supplied over the year. The main source of contamination of river water is from industrial effluents and city sewage disposed in to rivers. The surface water in natural conditions is generally good.

Groundwater quality is influenced mainly by rock composition as well as duration of contact and groundwater flow as well as oxidation reduction conditions and acidity/alkalinity. The duration of contact is often determined by the flow of water through the aquifers. Also, in coastal areas and marine sediments, salinity may be high.

Water quality for domestic use is assessed with following main parameters viz. Total Dissolved Solids (TDS), Chloride, Fluoride, Iron and Arsenic contents in water, which affects health. They exist in groundwater but in variable amounts. Measurement on electrical conductivity of water can indicate the amount of TDS in it. Hardness affects the taste of water Cooking takes longer time with hard water. Soap consumption increases with hardness of water.

Salinity generally refers to sodium chloride content in water. In the coastal areas the salinity of groundwater is found high. Apart from the natural reasons, it can also be attributed to over pumping of fresh water due to which saline water intrudes in coastal aquifers.

Arsenic as well as fluoride is toxic even in very small quantities. Groundwater from igneous terrains, especially in semi-arid and arid regions can contain more fluorides than acceptable limits. Arsenic is generally found in deep sedimentary aquifers. In India it is reported from lower Indo-Gangetic basin.

Table 15 provides an overview of groundwater quality parameters in different formations. The permissible limits for each parameter as per BIS are also given for understanding purposes. Impacts of poor water quality on health and daily activities are also listed in the table.

Aquifers can also be contaminated by pollutants entering during the recharge. With over exploitation of the groundwater water table goes down and borewells are drilled deeper. In deeper aquifers groundwater quality may be lower, especially in coastal regions with deeper saline aquifers underlying shallow freshwater. In urban areas mixing of sewage from leaking sewers can also contaminate the urban aquifer permanently.

Groundwater quality studies by Central Ground Water Board (CGWB) indicate that over the years, the groundwater quality has deteriorated in some parts of country (CGWB, 2010). The following section provides brief on some specific contaminants i.e. Fluoride, Arsenic and Selenium observed beyond permissible limits in the groundwater of some parts of country. Occurrence of these trace elements in water can impose serious health related issues.

Table 15: Groundwater quality in various formations and their impacts

Common Water Quality Issues	Permissible limits drinking water (in mg/l)	Impacts on Health	Other impacts
High Total Dissolved Solids (TDS) & Hardness Iron, Chloride, Fluoride depending upon nature of rocks (minerals) & climatic condition. Nitrate from sewage or fertiliser pollution Occurrence of Arsenic, mostly found in alluvial deep aquifers Salinity in coastal areas	TDS <500 Total Hardness <300 Chloride <250 Fluoride <1 Iron <0.3 Arsenic 0.05 Selenium 0.01	High TDS waters have Unacceptable taste Digestion related issues can occur Though hardness does not impose serious threats to health, it affects daily activities More Fluoride causes decay of tooth enamel and deformation of bones resulting in disability Excess of Arsenic can damage liver and kidney and cause skin diseases Hair loss, acute and chronic toxic effects in animals--"blind staggers" in cattle are caused by excess of Selenium	High TDS and hard water causes scaling on the utensils and corrosion to pipes and equipment Hard water requires more soap to clean. Clothes become stiff after washing, Iron causes Brownish stains on clothes & utensils

Source: BIS 10500, 1991; TARU, 2013

3.2 Use of maps for colony/neighbourhood level assessment

Maps can be used to collect and present spatially explicit information. The spatially explicit information includes resources, infrastructure, house types and population living in different buildings. Also some of the livelihood and income information from households can be analysed and presented through thematic maps. Clarity regarding the purpose and theme is necessary while using the maps. Not more than one theme should be shown in one map. Clear legend should be created and shown in base maps for collecting data.

In community context analysis, water infrastructure with their details (*e.g. functional or non-functional*), waterlogging areas in community, roof characteristics of houses (e.*g. tin sheet or RCC*), location of pipelines and drainage system can be easily mapped using participatory GIS methods. It can be further informed by the questionnaire based surveys. World café can be a good tool to collect spatially explicit data from participants.

Maps can provide synoptic view of community situations (*e.g. water logging in special part of community, most preferred water source*) as well as spatial relationships between different issues and can be used in FGDs to present the current situation of various infrastructure to initiate discussions.

The map assisted discussions is a useful way to discuss with illiterate or less literate groups. They can be used to gather generic information on water sources in community, historical development of resources, changes occurred in the settlement over years, other infrastructure available in community and so on. Participatory GIS (PGIS) is an approach to collaborate and share spatial information with communities.

Base map is necessary for starting the information collection process. With the free availability of Google Earth imageries for most cities base maps can be drawn easily without having to topographic maps, which are generally old and do not reflect the recent situation on ground.; A handheld Global Positioning System (GPS) receiver and a cost effective GIS software can improve the efficiency of map analysis and presentation In order to collect map based information from communities following steps are required

3.2.1 Base Map Preparation:

As the name indicates, base maps are fundamental maps that can be used to add more information from the ground. Base maps can be prepared by using:

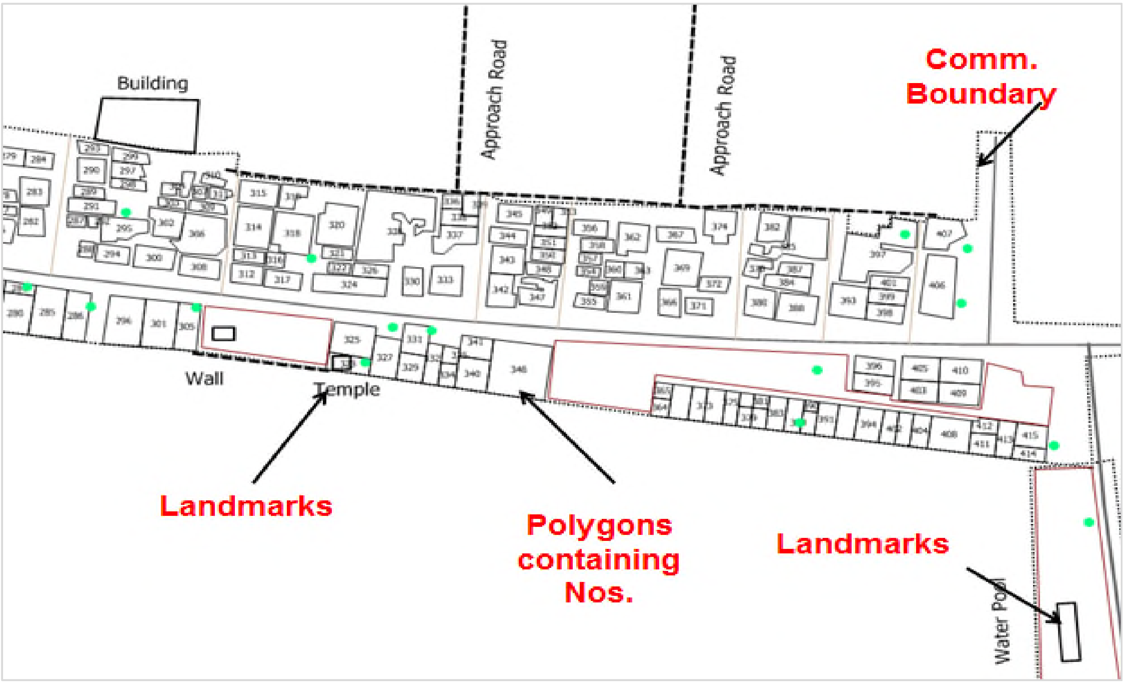
a. Google Earth and standard GIS packages (Manifold, ArcGIS) or open source GIS packages (Quantum GIS).Community boundary, important landmarks in and around community, building footprints, open areas; gardens etc. can be marked on base maps. The base map should have legend scale and north arrows marked. A grid of suitable interval can be used if necessary.
b. All the houses in the community can be marked as polygons and unique number can be given to each house for linking them with questionnaire based data to prepare GIS maps.
c. The base maps must be verified in field before conducting actual surveys using them.

Following Figure 13 and Figure 14 are examples of base maps prepared from the Google Earth imagery and GIS package for one of CWM project community in ACCCRN programme. Elements like community boundary, landmarks, roads and open areas are marked in the base map. Each building in the community is given a number (polygon number) as unique identity. Questionnaire based information collected from field was linked with the maps and thematic maps were prepared.

Figure 13: Settlement base map prepared from Google Earth

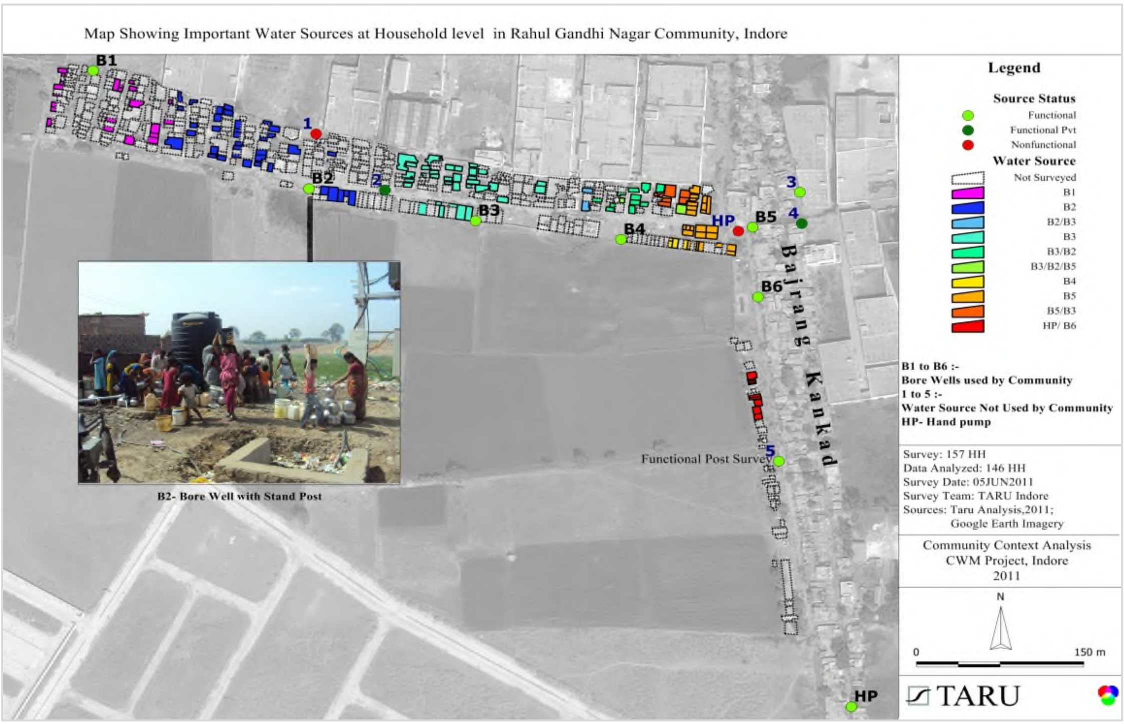
Source: TARU CCA exercise, 2011

Figure 14: Community base map with attributes



Source: TARU CCA exercise, 2011

Figure 15: Example of thematic map prepared using GPS and GIS tools



Source: TARU CCA exercise, 2011

3.2.2 GPS use for data collection from field:

1. Handheld Global Positioning System (GPS) receiver can be used to mark ground features like individual houses, borewells, land marks etc. Features can be recorded in the form of points (e.*g. borewell location*), lines (*e.g. water supply*

line or road) and polygons (e.*g. garden, house, septic tank or water logging area*) and are saved as data.

2. Data can be transferred or linked to Google Earth or any GIS software. Features collected from settlements can be viewed on map as points, lines and areas to understand spatial coverage with their details.

3. Following data is can be used to prepare water infrastructure maps using GPS:-

   a. ***Water Infrastructure***: locations of community and private borewells, water supply network, and overhead tank locations etc. in community.

   b. ***Service infrastructure:*** Approach and internal roads, sewerage and drainage network, solid waste disposal sites, location of septic tanks (*private or community*), open areas and gardens, in the community.

3.2.3 World café and Participatory GIS

World café is a tool for quick collection of information from a set of small groups with a mediator. In this case, data on three four themes (water supply, drainage etc.) can be collected using the maps with small groups. It is conducted as a workshop with 20-30 members from community. The members are split into four to five groups, with each group fairly homogenous and representing one part of the settlement. All the members first spend about 10-15 minutes identifying their house and note down the polygon number. Alternatively, GPS can be used previous day to get the exact location of each participant and it can be marked on the base map before the exercise starts.

A set of facilitators having good knowledge about issues to be covered would aid data collection process. A facilitator would cover one theme and he would work with a group for about 15 minutes to half an hour getting all information regarding the theme (e.g. source and collection of water from each household of the group). Then the participants move to the next table and cover another theme. At the end of the workshop all members would have covered all themes.

In each facilitator's table, the small group discusses the theme and then provide the thematic information in a structured format. Colours or patterns are used to present the status based on fixed legends. Multiple related issues can be mapped using more than one base map. At the end of the exercise, the final maps can be presented to the common participant group to further discuss the issues, if necessary.

Since each group is small, the data collection would be easier with minimal differences in opinion. It also helps in providing voice for each participant, without getting suppressed by dominant individuals.

3.2.4 Questionnaire based household surveys

To understand socio-economic background, water availability status in community; household surveys are important. Information on water supply sources, water quality available at household level and water consumption patterns etc. can be collection with questionnaires. In case of small community (fewer houses) 100% household coverage with survey possible, while in case of large communities maps can be used to select samples randomly distributed over space.

Following issues are covered in a questionnaire for household surveys:

a) **Socio-economic information**: Family size, education and skills, occupation of male and female members, Asset related assets, social capital, dependent family members (**Annexure 1**)

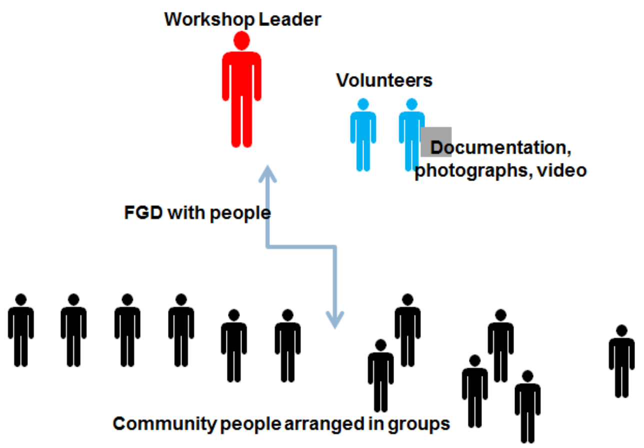
b) **Water information**: Preferred water source (internal & external), water availability, storage facilities, daily water consumption, quality perception, water management during scarcity (**Annexure 2**)

3.2.5 Focused Group Discussion (FGD):

Apart from household surveys, FGD can be used as a tool in the CCA exercise. FGD is useful to elicit information as well as to sort out issues of common interest. It provides an opportunity to initiate dialogue with community groups on daily water related issues. Qualitative information regarding existing institutions in the community (e.g. residential welfare associations, self-help groups, festival groups, project formed groups if any) and their performance can be explored through FGDs. Assessment of community cohesion as differences, if any, also can be done. Intervention options as well as possible structure and composition of community committees, identification of leadership and willingness of people for ownership can be assessed in FGD.

FGDs require extensive preparation and analysis of the information collected from World café and household surveys. The check list of issues to be discussed should be prepared and time should be allocated for discussing each issue. Logistic and other requirements for conducting FGDs should be prepared in advance. To get the inputs from the weakest, care should be taken to identify homogeneous groups for each FGD. Separate FGDs among men and women as well as marginal groups within the community would be necessary to get diversity of opinions.

Figure 16: FGD procedure with community groups



Source: TARU, 2011

The FGD requires at least one leader and two volunteers. The leader would conduct dialogue with people on the issues. The first volunteer would document the process. The second volunteer manages photographic & video recording and other support activities. Following diagram represents a typical FGD set up than can be arranged with community.

3.3 Water Consumption and Quality Surveys

The purpose of water consumption survey is to assess water demand for various end uses and people's perceptions regarding different types of water, ownership of storage and filtration systems and waste water disposal methods and practices.

A Sample household level survey and with questionnaire is preferred. Daily and seasonal water consumption and estimates of wastewater from few subgroups across the settlement can be collected from sample households. Numbers of households to be selected for water consumption surveys should be based on size of community and represent diversity across the community. Water questionnaire should be informed by socio economic conditions and should be pilot tested and improved. Water samples from all sources used in community should be collected for water quality tests. Water hardness, conductivity/TDS and *e. coli* tests are minimum parameters that should be performed in standard laboratories to know water quality. Based on test results and suggested quality norms (WHO/national norms), suitable option for water purification or disinfection can be planned at household or community level.

3.4 Sample outputs from Community context analysis

Results from Community context analysis would include maps, and numeric information. To discuss further with the communities, it is better present the outputs in graphical from as much as possible so that even less literate potential users can understand the results and implications. Few results from the analysis are presented in the following section.

3.4.1 Household water consumption

Results from household consumption survey are graphically represented by using pie charts as well as Sankey diagrams. A Sankey diagram of a groundwater dependent poor household is presented in Figure 17**.**

Figure 17: Sankey diagram of water use : of low SEC family

Source: TARU, 2012

The consumption of water for various end uses and waste water (grey and black) discharge from house to various outlets is shown in the diagram. Sankey diagrams can be used to discuss the water related issues and develop options for various end uses as well as developing water treatment options.

3.4.2 Seasonal Scarcity, Water Quality and Water cost:-

Seasonal Scarcity:

It represents availability of water for household across the year in terms of supply & quantity in urban areas. The piped supply in urban areas is limited from few minutes to hours and even in some cases only supplied on alternate days. In the summer season (March to May) the scarcity increases and the market cost of water increases. Peripheral or peri-urban areas also face seasonal scarcity as they mostly depend on the groundwater sources, which either dry up or the tanker water costs increase due to increased demand and scarcity.

Water Quality:

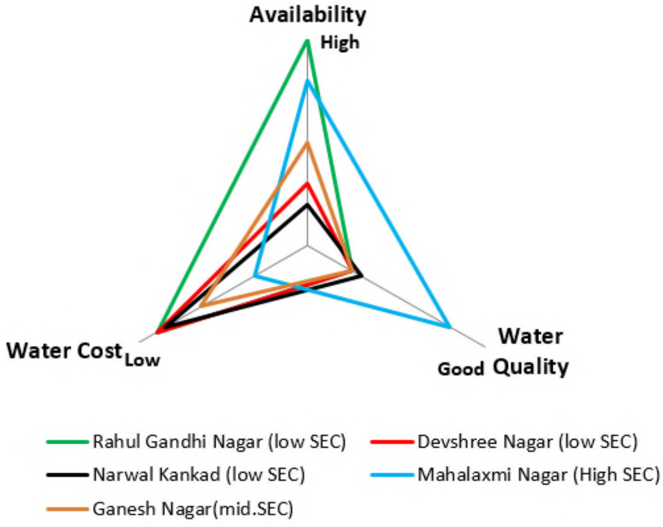
Since the piped supply in core urban areas is from government that provides treated water; the quality of water is more of a concern for groundwater dependency. Groundwater supply without purification increases chances of physical impurities (TDS, hardness) and bacteriological contamination in water. In most of the poor settlements groundwater is a major water source. The hardness and TDS parameters more than permissible limits in the groundwater and the occurrence of *e.coli* or *fecal coli* bacteria due to unhygienic conditions surrounding the water source (borewells), and unhygienic water handling practices affect water quality.

Water Cost:

In urban areas water is supplied at subsidized rates by the government. The capital and O&M cost is levied on the consumers at the time of new connections and yearly tax is charged. Groundwater extraction from motorized borewells consumes electricity. Energy costs are increasing. Purchase of water from private suppliers (tankers) in the scarcity season or due to non-availability of water, and purchase of bottled water is common in urban areas

To provide an overview of these three factors, an example from the study communities under CWM project is presented in the Figure 18.

Figure 18: Seasonal Water scarcity, quality and cost in CWM project communities



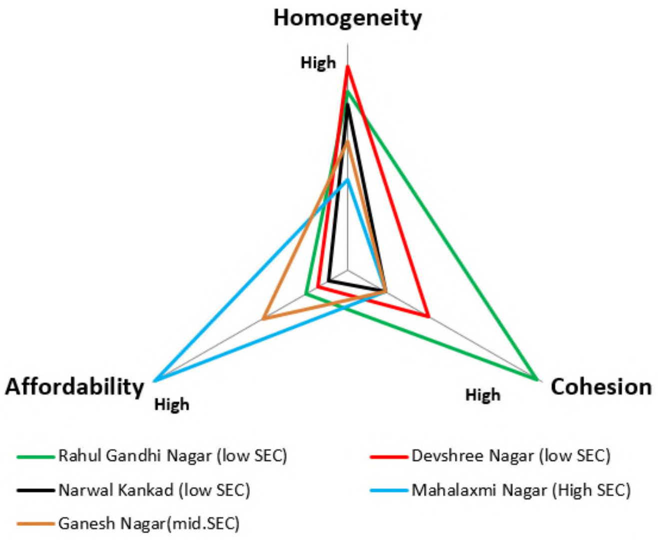
Source: TARU, Analysis, 2012

The above figure shows the diversity of water situations between different types of communities in Indore.

3.4.3 Homogeneity, Group (cohesion) and Affordability:-

Based on socio-economic surveys and FGD the three main social and economic issues relevant to scoping of technology options were explored for project communities. The affordability parameter as per occupation of people in community was added to understand feasibility of implementation of options involving financial costs. It can indicate possible contribution from community in terms of capital costs as well as water user tariffs. The comparative results are presented in Figure 19.

Figure 19: Homogeneity, Cohesion and Affordability across project communities



Source: TARU 2012

Comparison between prospective communities provide insights to possible interventions based on resource, infrastructure, social and economic contexts.

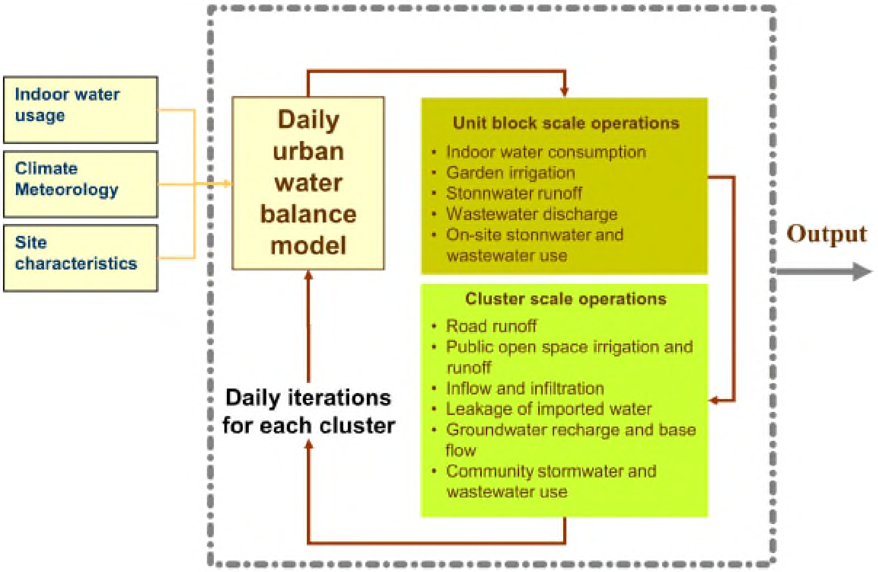
3.4.4 Water demand and resource assessment at community level

From the household level water consumption and population data, community level consumption as well as water balance can be worked out. Public domain tools like Aquacycle can provide aggregation of the data to community level and can also calculate water balance. Aquacycle is a daily urban water balance model which has been developed to simulate the total urban water cycle as an integrated whole and provide a tool for investigating the use of locally generated storm water and wastewater as a substitute for imported water alongside water use efficiency. The model is intended as a gaming tool rather than a design tool, giving an overall impression on the feasibility for using storm water and wastewater at a particular site (eWater website). The outputs of Aquacycle can be used to workout local options for managing water in urban settlements.

Integrated water management is based on multi-dimensional approach to water management. Water resources i.e. rainfall, waste water, storm water can be optimally utilized as per desired usage. Efficient and appropriate water use of domestic grey water and rainwater are first steps towards sustainable urban water management. Mitchell et al. (2001) highlighted the use of storm water and wastewater as a potential substitute for meeting a part of the fresh water demand. The Aquacycle model analyses water flows through the urban water supply, wastewater and storm water systems can be obtained from eWater website.

The Aquacycle analyses opportunities to utilize storm water and wastewater generated at various stages from natural (rainfall) and imported system. This is obtained by characterizing the supply of urban water and wastewater, demand criteria for various urban water usages in terms of quantity and quality. The tool estimates average monthly demand for household and grey water and black water discharge. Surface and storm water runoff during rainy season. Following Figure 20 presents Aquacycle model structure.

Figure 20: Layout of Aquacycle model



Source: Mitchell et al., 2001

The community context analysis results and other data sources can be used for Aquacycle as presented in Table 16.

Table 16: Data inputs in Aquacycle

Inputs Required	Data	Sources
Climatological Data	Daily precipitation and Evapotranspiration	Global Historical Climatological Network
City/Settlement Characteristics (Land Use & Land Cover)	**Community level data including**: Open space area; Construction area; Paved area including roads; Garden areas	Google Earth satellite imagery, GIS tool for length and areas measurements
	Household dimensions: Plot area; Roof area; Open space/Garden; Household size	Household surveys
Indoor water usage profile	**Daily water consumption** pattern across households sizes; Drinking & kitchen; Bathing & cloth washing; Flushing, floor cleaning & vehicle washing; Gardening/irrigation	Water consumption surveys

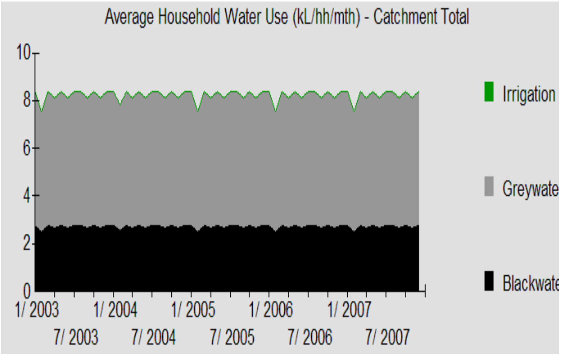
Source: eWater website

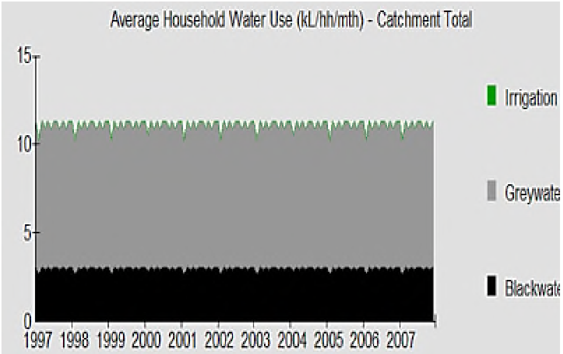
Following Figure 21 provides estimates derived from Aquacycle model in CWM project communities for various socio-economic classes. The tool provides important inputs to plan for water supply augmentation with rainwater harvesting at household level or planning for waste water recycling at community to utilize it in irrigation/gardening or in meeting low end usage requirements like flushing.

Figure 21: Household and community level Outputs from Aquacycle model

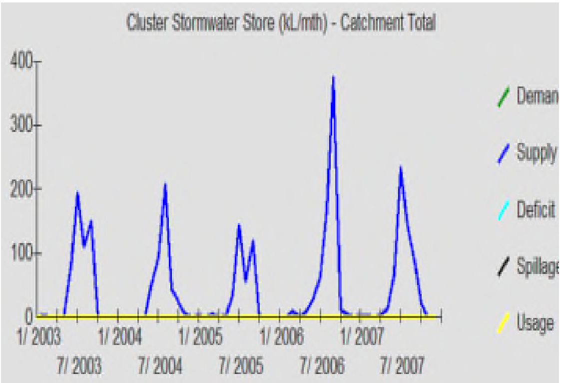
Middle SEC	Low SEC

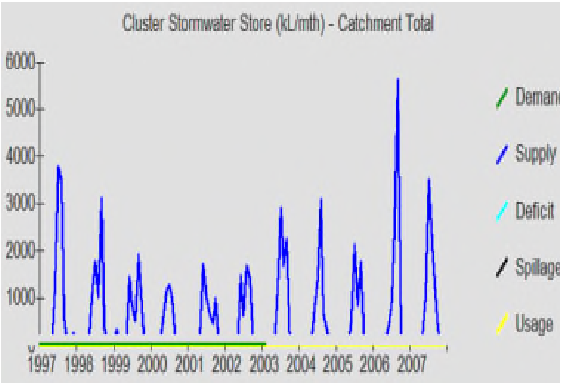
Average household level wastewater generated (KL/HH/month)



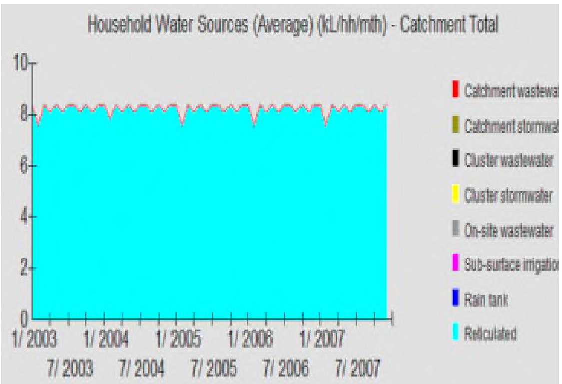


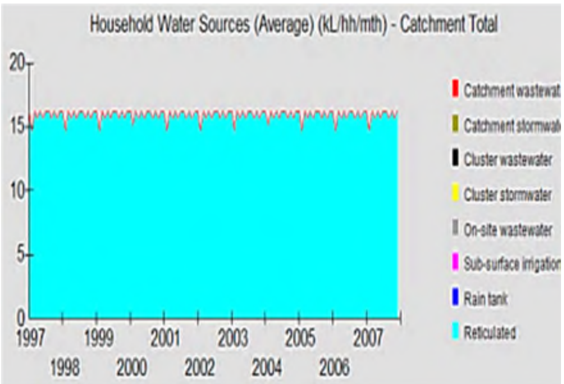
Cluster level storm water generated (KL/month)





Household water source with average availability (KL/HH/month)





Source: TARU, 2012

3.4.5 Future water demand assessment

Urban settlements and population grow over the time. Urban or peri-urban settlements expand by a combination of building vertically or horizontally. In most peri-urban areas, the development is often haphazard, starting with new buildings built with autonomous arrangements for water supplies as well as sewage disposal (often septic tanks). Roads, water supply and sewerage networks are often built later. More buildings are built over time and population increases. These land use changes affect the water cycle of the settlement. Groundwater exploitation becomes more intense, while the septic tanks may increase groundwater pollution especially in sandy soils. With increased paved areas, the natural recharge decrease and surface runoff increases.

The time series google earth Imagery, community mapping exercise, water infrastructure assessment at household and community levels and household surveys in CCA provides vital information to assess growth and estimate future water demand. It is advisable to trace the recent history and estimate number of new houses and population growth to get further cues for estimating future demands. Time series imagery from Google Earth can be used to understand changes over last few years. Infrastructure details collected by the surveys can be used to estimate impervious areas as well as roofs areas that can be used for rainwater harvesting (tin sheets, RCC etc.)

The baseline data obtained from CCA and population projections provide a basis for estimating future water demands at settlement level. Since it is difficult to imagine the population growth for specific community, the population projection of community can be done by following three methods. It is up to the user to select appropriate methods to project the population and water demand growth.

Figure 22: Projecting population growth and future water demand

Population growth rate similar to the city growth rate.	Community specific growth rate	Filling of empty plots
This scenario assumes the settlement population growth rate is same as the city population growth rate	This scenario is based on analysis of time series imagery from Google earth or other sources. The growth in umber of buildings and average household size are used to estimate the population growth rate	This scenario assumes filling of all open spaces with buildings of same type as the existing buildings and same building level population densities

Source: TARU, 2012

Household and community level estimates of daily water consumption and waste water discharge (grey and black) can be used for assessing the current demand. It is necessary to understand the penetration of water intensive appliances at household levels to estimate the additional demand growth from these changes. The projected population data can be used for simulation through Aquacycle software to get estimates of future water demand and supply requirements.

3.5 Selection of suitable technology options

The seasonal water availability; poor water quality and increasing cost of water are major issues that are faced by urban communities. The scale and priorities of these issues vary widely across communities and the CCA exercises provide inputs for shortlisting technologies based on the local contexts. The technology options would need to address one or more of these issues:

a) Improve water availability

b) Improve quality
c) Reduce costs

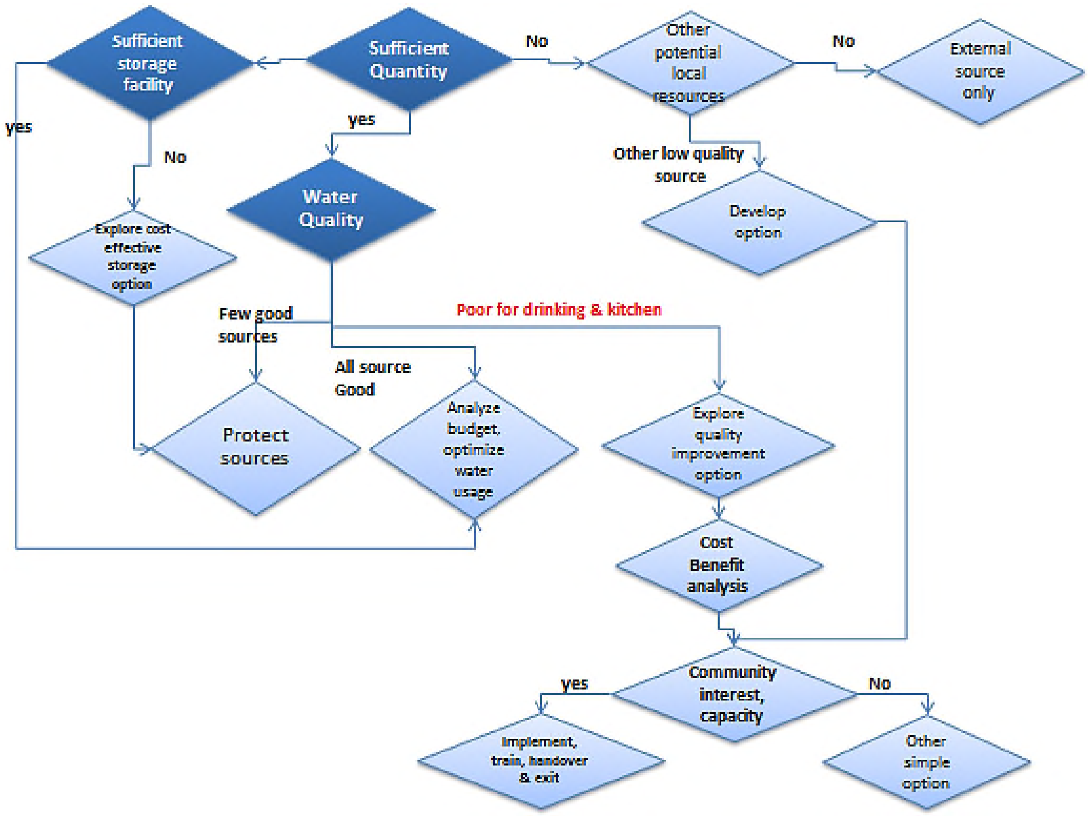
Also, the interventions should meet the following criteria:

- It addresses at least one of the top priority water issues in the community
- Affordable in terms of user charges (where relevant)
- Costs should include
    - Operational costs including staff, electricity, consumables etc
    - AMC costs,
    - Recovery of capital costs over the life of the plant
- Manageable mostly by the communities themselves
- Scale of interventions suitable in socio-economic situations (household or community level)

It is preferable to explore household level options, if any intervention are to be taken up in less cohesive communities.

Results from CCA and further discussions with the community, possible options can be shortlisted. Future water demand assessment, water budget estimates and affordability and willingness should inform the type and scale of interventions. Community mobilization is required prior to any intervention in the community. Figure 23 provides generic approach for identifying suitable solution on following three fronts.

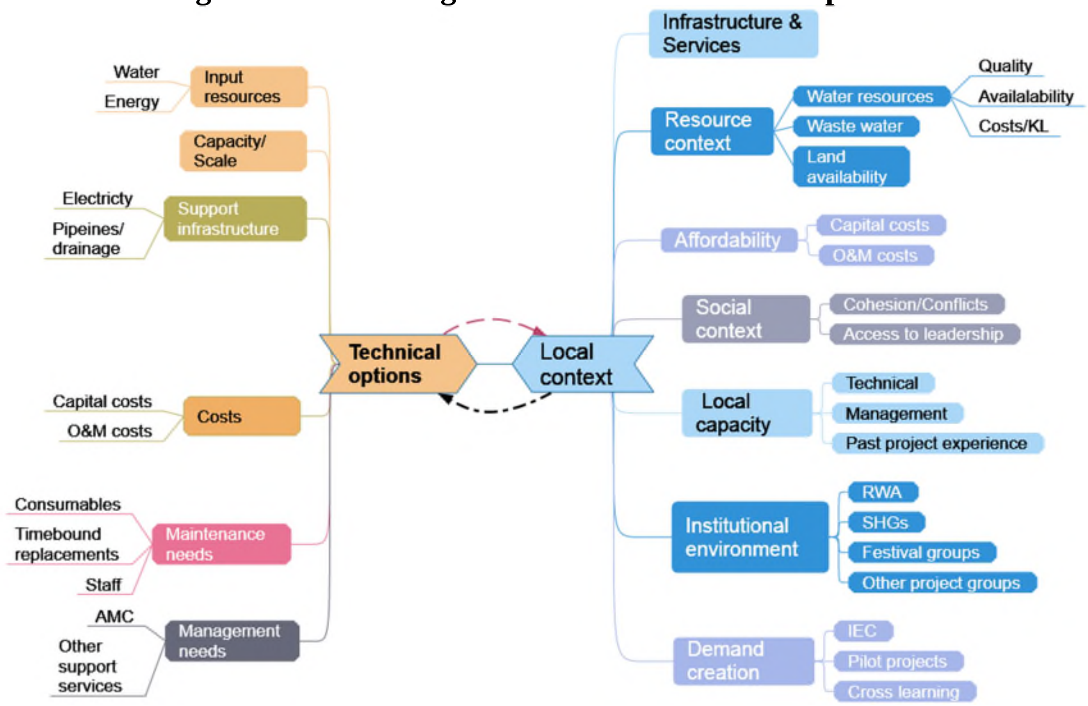
Figure 23: Indicative approach to identify options



Source: TARU, 2012

Important issues to be considered for assessing and shortlisting intervention options are presented in Figure 24. As shown in the diagram, the technical option should satisfy the local context in order to become self-sustainable. Capital and O&M costs as well as the capacity of the communities to maintain the water system are crucial to sustain the assets created by the project.

Figure 24: Matching local context to technical options



Source: TARU, 2012

Similarly the local capacities of leadership, financial management and social cohesion are important for sustaining community based interventions. Choice of technical options has to be informed by the local context and it is necessary to assess the viability from different perspectives before selecting the intervention. Availability of land, electricity connection and permission to use water sources may need to be assessed. Support from ULBs and line departments like Electricity, water supply etc. may also be necessary to optimise capital as well as operating costs.

3.5.1 Workbook for the selection of technology option

The technology option should be based on water demand, settlement size, building types i.e. single, multi-storey as well as commercial establishments in the settlements. A work book created in excel has been provided along with this guidebook. Daily domestic and commercial water requirements of the house units is to be provided as an input to estimate annual water consumption and waste water discharge of the settlement. Water budget is calculated for entire settlement based on rainfall of the region and various land use parameters. As per the soil type and slope, surface runoff and groundwater recharge are estimated for the settlement.

Roof sizes of various building types are to be provided as an input.

The workbook provides options to optimize storage tank capacity as well as borewell recharge potential. Similarly based on the waste water discharge estimates, capacity of the sewage treatment plant to recycle waste water is also provided. As per the treatment efficiency and costs, payback period is calculated for the waste water recycling plant. The cost estimates providing the payback period for the development of infrastructure required for the rainwater harvesting or waste water recycling plant are based on water costs. As discussed earlier. Poor water quality is also an important concern in urban areas especially in poor settlements. Based on the primary water quality parameters of hardness and bacteriological contamination; selection of water purification or disinfection systems along with the cost layout and payback period can also be calculated in the workbook.

List of Feasible Technology Options in Urban Context

4 List of feasible technology options in urban context

This section presents a suite of relevant technology options s that can be considered to resolve water related issues faced by households or communities in urban areas. The technologies are explained in simple form so that the communities as well as implementers can easily understand them. It is suggested to combine both demand as well as supply side interventions to improve resilience of the systems. It is suggested to consider near-future demands also, while designing the water systems. Community ownership and management model is best suited for decentralized water supply and wastewater treatment systems.

The middle and upper SEC communities can be expected to meet at least part of their water demand from centralized supply over time. It is not advisable to implement any projects where the municipal supply may be installed in near future, since it may lead to neglect of the infrastructure created.

The poor SEC settlements are expected to rely on local sources due to barriers to access and/or elite class capture in scarcity environments. The communities show high level of diversity in endowment of resources as well as affordability and social cohesion and willingness to engagement.

4.1 Roof top rainwater harvesting (RTRWH) & Recharge pits

Traditionally, rainwater harvesting has been practiced for over 4,000 years throughout the world in arid and semi-arid areas for meeting domestic use and irrigation water demands. It was quite common in Buddhist monasteries (*Mumbai*) and in arid parts Rajasthan (called '*Tanka'*) in India. After near extinction of the technology driven by extension of centralized supply and limited dependency on groundwater, the rainwater harvesting is now again promoted as a modern water technology in urban areas to improve the groundwater recharge for meeting the increasing water demand.

It is important to understand the rainfall pattern to design water-harvesting systems. The annual rainfall, variability in rainfall, distribution across the months and intensity of rainfall are important parameters to decide on the type and scale of water harvesting systems.

RTRWH is an option (*TO sheet: Rooftop rainwater harvesting)* for collecting and storing the rainwater from roof top runoff, which otherwise flows into the drainage. Either it can be channelized to groundwater for recharge purpose (*TO sheet: Recharge Pits*) or it can be stored in appropriate storage tanks. In monsoon dominant rainfall regions, storage of all the rainwater may not be feasible, so it is better to combine direct rainwater harvesting to tanks with borewell recharge systems.

Being a decentralized and low-cost technology, rainwater harvesting enables people at household and community level to manage their own water and thus can be adopted easily. Also the rainwater storage tanks can be used to store tanker water during summers.

For the purpose of calculation of runoff from roofs, about 70% of the annual rainfall can be assumed in semi-arid tropical areas with low humidity. The storage required can be as low as one fourth of the total runoff, since rainfall occurs during short wet spells separated by long dry spells even during monsoon in this semi-arid region. Therefore, with about 70% of rainfall flowing as roof runoff, each 10 sq. m of roof area requires about 1,500 litres of storage considering four fillings during the rainy season.

Rainwater harvesting, provides certain benefits during rainy season and reduces reliance on central water supply systems (government piped supply/borewells) which are either unreliable or too expensive for poor communities. RTRWH infrastructure can also help in saving effort and time spent on water collection, which can be spent on other economic activities by poor families. Moreover, rainwater harvesting can greatly reduce water scarcity in poor communities by increasing storage without sacrificing scarce indoor space. The storage can be innovatively used to deal with water scarcities during non-monsoon periods also, as is being done by many households in rural areas. These can be used to access tanker supplies by two or three families, which can use this water for drinking only for couple of weeks, thereby reduce dependency on public sources to a great extent. It can indirectly reduce the expenses towards water otherwise purchased in retail at much higher costs.

Rain Water Harvesting in Urban India

The Municipal Corporation of Indore, India has already been noticed to ban any new installation for groundwater, except for drinking water purposes, and even then, special permission will have to be sought from the district administration **(CGWB, 2006)**

The Madhya Pradesh government has initiated measures for recharging of groundwater by implementing construction of rainwater harvesting structures. The Land Development Rules have been modified once in year 2000 and later in 2001 and stipulate mandatory construction of rain and water harvesting structures for plots bigger than 250 sq. m. (~2700 sq. ft.). Until March 2004, the local bodies had granted building permission to 18,256 cases with provision of rainwater harvesting structures. Of these 1,557 (8%) are reported to have complied with these provisions. **(Water Aid India, 2005)**

Govt. of Karnataka, through the Rural Development and Panchayat Raj Department has launched a rooftop rainwater harvesting program for 23,683 schools across the state. The schools have been selected on the basis that they do not have any source of drinking water currently. The program seeks to provide each student with 1.50 litres of drinking water per day through harvesting rainwater from rooftops of the schools. The construction component of the program is being implemented by the Engineering Department of the various Zilla Panchayat or by the District Nirmithi Kendra. **(www.arghyam.org)**

Roof Top Rainwater Harvesting

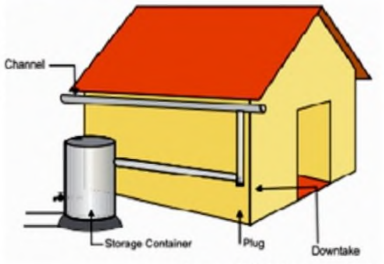
Purpose

With rainwater harvesting, water falling on roof top is tapped that otherwise goes off as surface run off. Water is harvested from roof tops for (a) storage purpose or (b) groundwater recharge purpose. Storage and recharge can also be done together for maximum benefit. Stored water can be used for low end usage purpose and reduce burden on fresh water resources and with recharge the groundwater conditions improves. From Catchment (roofs), water is conveyed through gutters (PVC pipes), filter media is used to remove the pollutants from the water before recharge or storage.

Rainwater harvesting potential can be estimated as following :-
Roof area (sq. m) x rainfall (mm) x efficiency of roof type (%)
For example for 50 sq. m. roof area, rainfall of 1,000mm and roof efficiency 80%, the seasonal rainwater harvesting potential will be about 40,000 liters.

Suggested Adaptation Scale

Household Level	Community level
City level	



Source: WHO Blue Drop Series

Prerequisites

1. Clean roofs with unidirectional slope to convey rainwater in recharge pit or storage purpose
2. Sufficient space for storage tank within premises
3. In case of water harvesting from big catchment areas, large open space is required either for storage or construction of recharge pits purposes.
4. Retrofitting of roofs especially in poor settlements where roof types and slope vary from house to house

Retrofitting required for non-uniform roofs in slums

Benefits

1. Reduced dependency on central supply at least for few days in case water is stored
2. Extended usage of groundwater sources that goes dry or gives low yield in February or March before starting peak summer with recharge option
3. This can reduce the tanker dependency and expenditure on water purchase in summer
4. Energy bill is reduced with water table coming up with groundwater recharge and reduced load on motors.
5. Groundwater quality is improved (reduced hardness) with inflow of freshwater.
6. Storage of roof water for low end usage (washing, flushing, gardening etc.) reduces stress on high quality groundwater sources

Indore city of Madhya Pradesh, India falls in semi-arid region with 1,000 mm rainfall in a season. Groundwater is important source of water in city. Municipal Corporation Indore has separate department for doing rainwater harvesting in various wards of city. It is the only municipal corporation in India that has rainwater harvesting department. City level adaptation has improved the regional water table .

Constraints

1. Deep aquifer recharge is difficult by this method
2. Adopting this option for storage purpose requires sufficient space and periodic water quality monitoring

TARU, 2012-13

TARU

Cost

Material Required	Cost (Rs.)	Filter Cost	Cost (Rs.)	Labor /Transport Cost	Cost (Rs.)
PVC pipes & Valves	2,182	PVC tank (90 liters)	400	Plumbing & Fitting	1,500
Accessories (PVC + metal)	1,370	Charcoal	125	Filter preparation	1,200
Water reducer (4"x3")	117	Brickbats & sand	200	Transportation	100
First flush pipe with a cap	200	Cement	90		
Valves (7mm)	450	Mesh	100		
Total Cost (Rs.)	3,869		915		2,800
Sum Total (Rs.)	7,584	Seven thousand five hundred eighty four rupees			

Cost given above is for installation of one rainwater harvesting kit in a low income house of CWM project community under ACCCRN program in Indore city.
5 to 10% of capital cost can be expected towards annual maintenance in case filter media (charcoal, sand, gravel) is replaced due to clogging over time

Rainwater harvesting potential table:

Following table provides estimates on potential of roof top harvesting from various roof sizes. Roof sizes and rainfall are given in the table. With respective roof size of house and rainfall received in the region, rainwater harvesting potential can be estimated from this table. For example, as shown in a table, a house in region receiving 1,000mm of rainfall in monsoon season and having roof size of 50 sq. m. can tap 40,000 liters of water either for groundwater recharge or storage purpose for low end usage.

Roof Size		Rainfall (in mm)												
(sq. m.)	(sq. ft.)	100	200	300	400	500	600	800	1,000	1,200	1,400	1,600	1,800	2,000
		Volume of water that can be harvested (in cum)												
20	216	1.6	3.2	4.8	6.4	8	9.6	12.8	16	19.2	22.4	25.6	28.8	32
30	324	2.4	4.8	7.2	9.6	12	14.4	19.2	24	28.8	33.6	38.4	43.2	48
40	431	3.2	6.4	9.6	12.8	16	19.2	25.6	32	38.4	44.8	51.2	57.6	64
50	539	4	8	12	16	20	24	32	40	48	56	64	72	80
60	647	4.8	9.6	14.4	19.2	24	28.8	38.4	48	57.6	67.2	76.8	86.4	96
70	755	5.6	11.2	16.8	22.4	28	33.6	44.8	56	67.2	78.4	89.6	100.8	112
80	863	6.4	12.8	19.2	25.6	32	38.4	51.2	64	76.8	89.6	102.4	115.2	128
90	971	7.2	14.4	21.6	28.8	36	43.2	57.6	72	86.4	100.8	115.2	129.6	144
100	1,078	8	16	24	32	40	48	64	80	96	112	128	144	160
150	1,618	12	24	36	48	60	72	96	120	144	168	192	216	240
200	2,157	16	32	48	64	80	96	128	160	192	224	256	288	320
250	2,696	20	40	60	80	100	120	160	200	240	280	320	360	400
300	3,235	24	48	72	96	120	144	192	240	288	336	384	432	480
400	4,314	32	64	96	128	160	192	256	320	384	448	512	576	640
500	5,392	40	80	120	160	200	240	320	400	480	560	640	720	800
1,000	10,784	80	160	240	320	400	480	640	800	960	1,120	1,280	1,440	1,600
2,000	21,568	160	320	480	640	800	960	1,280	1,600	1,920	2,240	2,560	2,880	3,200
3,000	32,352	240	480	720	960	1,200	1,440	1,920	2,400	2,880	3,360	3,840	4,320	4,800

1 cum=1,000 liters

Recharge Pits

Groundwater source augmentation

Suggested adaptation scale

Household Level | **Community level** | **City level**

Purpose

1. Rainwater falling on roofs is diverted in a pit filled with brickbats, boulders, grit, and gravel etc.
2. Water percolate in ground and recharge groundwater source
3. With groundwater recharge, water table is maintained and water availability from bore well is extended in summers.

Prerequisites

1. Uniform and unidirectional slope of roof to convey rainwater
2. Clean roof tops to prevent contamination of rainwater
3. Water conveying pipes of at least 3" diameter to resist water pressure
4. Minimum 1mx2mx2m (WxLxD) space to excavate recharge pit
5. Pit should be few meters away from recharge bore well to avoid direct infiltration of water in aquifer.
6. With increased distance of recharge pit from bore well, filtration time will increase and water will be purified.
7. Uniform size of filter media (brickbat, gravel, sand) to improve water percolation

Cost

Particulars	Cost (Rs.)
Trench Dimension in ft. L x W x D (4x3x5)	
Labor	
Trenching pit	1,400
Filling pit with material	1,000
Masonry work (observation)	1,500
Material transportation	50
Material	
Filling material (Brickbat)	3,000
Sand	280
Cement	300
PVC pipes 3m (75mm)	160
Pasting door band 87.5" (75mm)	100
Total Cost	**7,790**

Above rates are based on construction of recharge pit in a CWM project community, Indore

Benefits

1. Low cost & maintenance and easy to adopt for groundwater recharge
2. Water availability from bore wells is extended that otherwise become dry in February or March before peak summer season in India
3. Energy charges are reduced as lifting of water is from shallow depth
4. Dilution in hardness of water with freshwater influx through recharge pit in aquifer
5. The tanker dependency (Cost) is reduced with extended availability of water from bore wells.

Maintenance

1. Requires very less maintenance. 5 to 10% of capital cost, in case filter media is changed with clogging in it with time.
2. Roof cleaning is required before monsoon so that water do not contaminate before passing through recharge pit

Constraints

1. Not useful to recharge deep aquifers
2. More adaptable at household level than at community level
3. Difficult to adopt in the hard rock terrains
4. Clogging can occur in filter media by siltation. This reduces infiltration capacity from recharge pit over time
5. Limited space in low SEC settlements

TARU

4.2 Storage tanks

In the informal and poor settlements, water is mostly collected from common and often distant resources. As scarcity grows and effort to collect water increases, the households minimise water consumption to a bare minimum. Per capita water availability often reaches as low as 40 lpcd. Lack of space (often 20 sq. m. or less) and uncertain land tenure restricts construction of adequate storage facilities i.e. underground or overhead tanks. Opportunity cost losses are very high in low SEC settlements. Low water consumption affects health and hygiene.

In the CWM project communities, it was observed that many households used sit out benches or verandas as storage place. However, due to non-affordability of readily available storage tanks, cans, drums and utensils are used in already limited space with risk of theft.

The readymade cement tanks vary in capacities starting from 300 to 1,000 litres. They occupy space from 10 to 15 sq. ft. & can be easily placed in front areas of houses. However, they are not covered. This increases water contamination by mishandling it as well as provide sites for mosquitoes breeding. Animals roaming on streets can easily access these open tanks kept in front areas of house.

Readymade tanks available in the markets were modified as per the requirements. Following sheet provides a modification of open tank for safe handling of water by providing a cover and tap. The tap and outlet pipes are provided at the base and opposite ends of modified tanks for usage and cleaning purposes respectively. The cost of such tanks is about Rs.6/lit. The cements tanks are cheaper and more durable options in the low SEC or poor settlements and cannot be stolen.

Storage Tanks

Suggested Adaptation Scale

Household Level	Community level
City level	

Purpose

1. Create a buffer stock of water for daily usage especially in poor settlements
2. Can be used to collect rainwater and store it for low end usage in monsoon season
3. Reduce time and energy wasted in water collection for other economic activities

Storage facility in low SEC communities

- In poor settlements water is collected from distant common sources either bore wells or hand pumps
- Daily low end usage water requirements for flushing, washing & floor cleaning for a household is around 50 to 70 liters
- Due to lack of space inside house and poor financial conditions the storage facility is not available
- Water stored in cans, drums and utensils that is kept in verandah or front areas of houses due to space constraint
- In this conditions chances of water contamination are high
- Insufficient water availability due to lack of storage facility leads to compromise in daily water consumption.
- Daily important activities like bathing, flushing, washing etc. suffers most in poor settlements
- Opportunity cost loss in terms of time and money are high for working women and education is suffered for children in water collection from distant sources in poor settlements
- The space utilized for storing water in cans and utensils can be used to place storage tanks

Prerequisites

1. About 4'x3' space is required to install readily available 500 liter capacity water storage tank
2. Front areas or verandah are suitable places to install the tank
3. In case of non availability of space above ground, underground installation can be done
4. Tanks are available in circular and cubic shape in the market. The tanks should be chosen to fit available space in house to install it
5. Storage tanks must be protected by providing cover so that water contamination does not occur

Benefits

1. Water availability at doorstep with buffer stock to meet daily water requirements
2. Daily low water requirements like bathing, washing cloths and utensils, flushing and floor cleaning activities can be performed
3. Time and energy saving that can be used for economical benefits by working females
4. Children can attend schools instead of time spent in water collection
5. Easily available in the market and ready to use
6. During monsoon season rainwater harvesting can be done to increase water availability at door steps instead of fetching from source

Cost

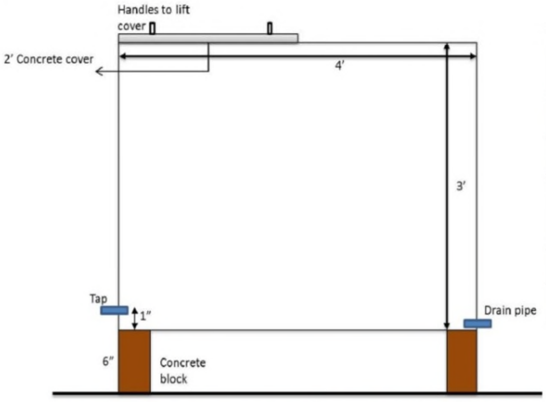
The cost of plastic storage tanks vary from Rs. 5 to 7 per liter.
500 liters tank will cost around Rs. 3,000 and 1,000 liter capacity will cost Rs.6,000.
Construction and installation cost of 500 liter cement storage tank is equal to plastic tank

TARU

Cement tanks

In one of the CWM project community, storage facility was found poor at household level (150 lit/HH). The water storage was in cans, drums and utensils. The surveys conducted indicated that there was space available in front areas of houses. There are readily available open storage tanks in local markets. These are generally used to store water for low end usage purposes or for cattle. However, in open tanks the contamination of water and mosquitoes breeding can occur.

These tanks were modified for the usage at household level by covering half of the length by providing a concrete cover. The remaining half portion was covered with lid with handle for filling and cleaning purposes. Provision of a tap for daily use and drain pipe was kept for washing purposes.



500 liters capacity tank cost (in Rs.)	
Ready made tank	2,000
Construction	500
Transportation & installation	500
Total Cost	3,000
Cost/liter	6

Plastic tanks

Loft Tanks
(Storage capacity 50 to 1,000 liters)

Circular tanks
(Storage capacity starts from 200 liters)

1. Ready made plastic tanks area available in local market.
2. They vary in sizes and shapes as shown in pictures
3. Due to breakage with mishandling in poor settlements the cements tanks can be more preferable
4. In summer the temperature in water stored in black colored tanks can be increase
5. For Underground installation, special plastic tanks are available which cost Rs.9/kl

TARU

4.3 Water purification

Water treatment systems: These systems are installed in houses and are available in a range of costs and sizes. However, these are unaffordable for the poor. Most of the low economic class communities do not have piped water supply and remain dependent on the public stand posts mostly attached with groundwater sources. The quality of the groundwater is major concern. In these circumstances, poor have to face two fold problems i.e. low water availability as well as poor quality.

Contaminants in the water can be removed by adopting suitable water purification methods. In Table 17 a summary of water purification methods is presented (NAFEN, 2010). The selection of appropriate method should be based on the quality of the input water.

Table 17: Summary of water purification technologies

Process	Aim	Methods
Pre-treatment	Removal of suspended and colloidal solids before filtration. To achieve optimal operation of filter, this is essential	Coagulation and Flocculation Sedimentation Tube and Lamellar Clarifiers
Filtration	The process removes suspended solids and microorganisms from water. Removal in a filter is highly dependent on the surface area of the media particles. Normally sand and gravel are used as media. Multimedia Filter (anthracite coal, sand and gravel) are being used to get higher filtration efficiency. Filtration process may work either by gravity or by pressure. Accordingly, they are termed as Gravity Filter or Pressure Filter.	Slow & rapid sand filters (gravity) Dual Media Filter (Gravity) Pressure Filter
Water Softening	Water Softening is the removal of certain dissolved minerals in water that cause scaling in boilers, form deposits on pipes and cause excessive consumption of soaps. Hardness in water is mostly due to presence of cations such as calcium and magnesium (divalent cations).	Boiling Lime soda softening Ion exchange
Membrane Process	This is used to separate dissolved and collided constituents from water. Water or components in water are driven through membrane under the driving force of a pressure, electrical potential or concentration gradient. Membrane treatment is used for filtration, removal of micro – organism, hardness, volatile organics and other soluble organics. Membrane Separation techniques include	Microfiltration Ultra-filtration Reverse Osmosis Nano-filtration
Adsorption	It is a physical process where soluble molecules (adsorbate) are removed by attachment to the surface of a solid substrate (adsorbent) primarily by Van-der Waals forces, although chemical or electrical attraction may also be important. Adsorbents must have a very high specific surface area and	Powdered Activated Carbon (PAC) Granular Activated Carbon Filter Activated Alumina

Table 17: Summary of water purification technologies

Process	Aim	Methods
	include activated alumina, activated carbon, clay colloids, hydroxides and adsorbent resins. Activated carbon is widely used for water treatment.	
Disinfection	Disinfection is destruction of pathogenic microorganism in water. The eradication of water borne pathogens is the most important treatment of water.	Boiling Chlorination Ozonisation UV Ray Solar Disinfection (SODIS) Silver

Source: NAFEN, 2010

Reverse Osmosis (RO) Technology

Reverse osmosis technology has become popular and RO plants are readily available in the Indian markets with capacities ranging from household devices (20- to 0 LPD capacity) to million litres per day for commercial usage. Some of the major issues of this technology are:

Affordability: Costs of household devices are high (Rs. 6,000-10,000 or 120 to 200 USD) and not affordable by poor households. Also, regular maintenance is an issue.

Energy requirements: Stable electricity supply is required for running the (RO) plant.

Brine disposal: A typical RO plant generates a waste brine water roughly equal volume as treated water. This water cannot be used for most domestic use since it is hard and has very high amount of dissolved solids (about 3,000 mg./lit. or more depending on the raw water quality). Only option remain is to use it for flushing in community toilets or neighbouring houses.

At community levels, about 20 litre of water per household can meet the drinking and cooking needs of a family. A community of about 1,000 households would need about 20,000 LPD towards drinking & cooking needs. A 3,000 LPH capacity RO plant working for about 7 hours including 5% bottle-cleaning can meet this demand. With a capital cost of about Rs. 1.5 million (including building costs), it is only about Rs. 1,500/household as capital costs for the RO plant. The O&M and local transport costs including capital cost recovery over 10 years comes to less than Rs. 5 /20 litres of purified water.

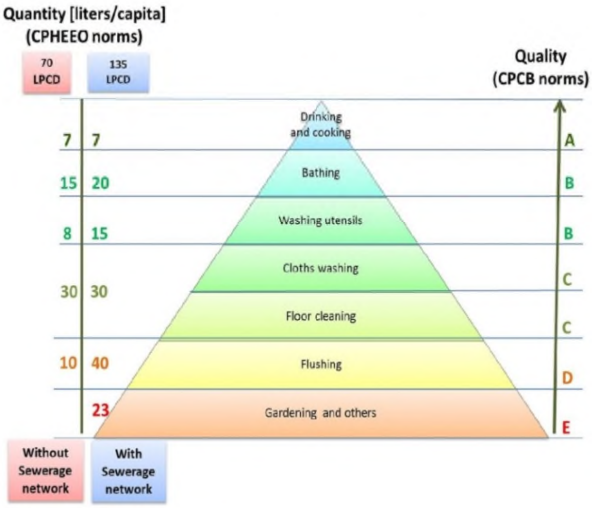
Community level RO plant would require social cohesion with sufficient sustained demand. In many low-income settlements, women work as housemaids in middle/high class households and know the difference in quality of local borewell water and RO water. Only the high price is the constraint (market price of Rs. 30 to 40 for 20 litres of RO water). When the communities are ready to adopt and manage the technology, such windows of opportunity should be best used to demonstrate these water quality improvement interventions especially in the poor settlements. Demand generation would require IEC activities and active promotion

Community Managed RO Plant

Background:

Low socio economic class (SEC) settlements depend mainly on groundwater source for daily water requirements. Poor water quality in terms of hardness and pathogen contamination is common and increase health risks. Cooking and milk curdling are common issues by using groundwater. Water borne diseases like malaria, diarrhea, jaundice are commonly occurring and increase medical expenses as well as affects livelihood.

Due to non affordability of miniature RO system, poor have no choice and use the poor quality water. Therefore, to address the poor water quality issues community managed water purification can be a good option to improve the living conditions.



The diagram shows daily domestic water requirements by person in various activities.

Left side in the diagram shows per capita daily water supply norms of Central Public Health Engineering and Environmental Organization (CPHEEO) in settlements with and without sewerage requirements. Right side indicates water quality norms by Central Pollution Control Board (CPCB) norms in India. A is highest quality water and D is lowest quality water. E indicates water quality for irrigation purpose.

As shown in diagram Drinking and Cooking requires high quality water. Other activities like flushing, washing, floor cleaning etc. does not require high quality water.

Drinking water quality criteria is pH 7, Hardness <500 mg/lit., and pathogenic contamination nil in 100 ml water.

For a household size of 5 members in the low settlements the daily drinking and cooking requirement is around 20 liters.

Purpose

1. To provide safe drinking water to poor at affordable cost
2. To improve living conditions and aspirations among people
3. To develop entrepreneurship for community groups and provide employment opportunities for people in community

Prerequisites

1. Community cohesion and able leadership to manage the system
2. Demand and willingness to pay for the purified water to main the plant
3. Land nearby water source in settlement that is legal in all aspects to construct building
4. Necessary permissions from government authorities for infrastructure usage i.e. water and electricity
5. If raw water is contaminated with pathogens UV treatment and Ozonization is required
6. Safe distribution mechanism in bottles tightly closed caps to prevent the contamination
7. Annual Maintenance Contract (AMC) facility

Benefits

1. Safe and affordable drinking water for poor using local water source
2. Protection from water borne disease (jaundice, diarrhea) and reduced health expenditure
3. Reduction of expenditure on medical bills
4. Utilization of rejected water from RO plant for flushing in community/individual toilets, washing and other low end usage activities. This reduces stress on groundwater source used in low end usage.
5. Increasing self reliance in low SEC settlement to avail safe drinking water and less dependency on ULBs and local politics.
6. Opening of new avenues of employment (plant operation, water distribution, repairing, etc.) within the settlement

TARU

Space requirements

Details provided below for space and cost layout are based on quotations received for the installation of 3,000 LPH capacity RO plant in 360 sq. ft. building

SN	Particulars	Detail
1	**Space Requirements**	**(in Sq. ft.)**
A	Building construction (1,000 LPH to 5,000 LPH capacity plant)	**300 to 500**
2	**Building construction cost in Rs.**	**1,000/sq. ft**

LPH is Liters Per Hour

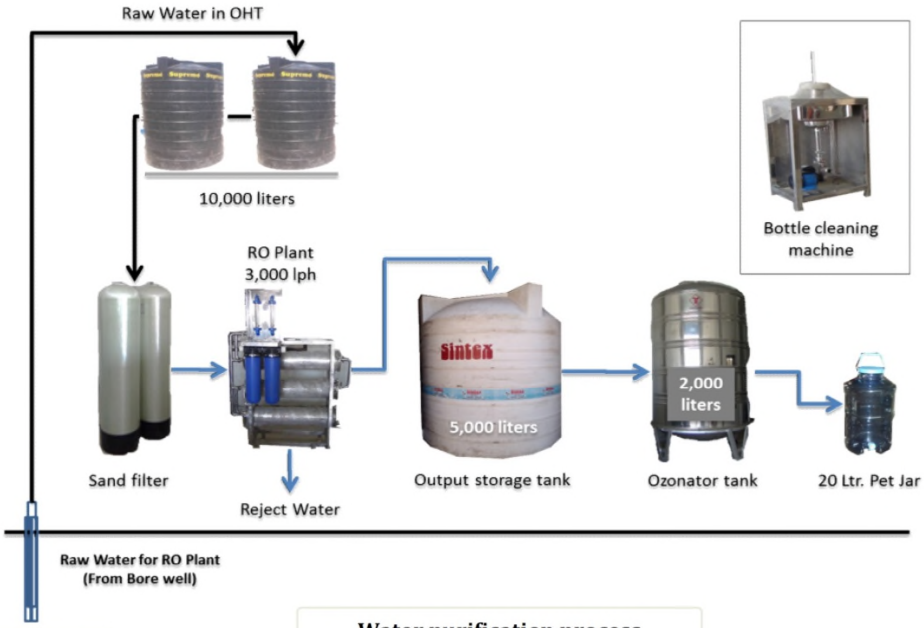
Capital Cost

Capital cost of RO plant (in Rs.)	1,000 LPH capacity	3,000 LPH capacity
RO plant cost	**250,000**	**450,000**
UV and Ozonator treatment units	**200,000**	**200,000**
Bottle cleaning machine	**45,000**	**45,000**
Raw and output storage tanks	**75,000**	**75,000**
Total Cost	**5,70,000**	**7,70,000**
Cost per 20 liters pet jar bottle with tap		**200**

Monthly O&M cost

Particulars	Cost (in Rs.)
Operator Salary	**5,000**
Energy cost	**2,500**
Antiscalant chemical	**3,000**
Consumable & maintenance	**1,000**
Total Cost	**11,500**
Above cost is towards water production for 250 bottles per day	

Expected life of plant: 5 years



Water purification process

Constraints

1. Financial arrangements for capital and monthly O&M cost in low socio-economic settlements. External support may be required
2. Suitable location nearby raw water supply with adequate space
3. Sustainability of system due to lack of ownership in the community

TARU

Chlorination

In poor settlements, the pathogenic contamination of water sources is common. The chances of contamination starts from source i.e. groundwater, collection utensils and handling of water at household level due to lack of awareness. The most commonly adopted, easy to use and affordable method is chlorination treatment to disinfect the water. The residual chlorine can protect the water from contamination for two to three days. The following sheet provides benefits and usage of chlorine treatment to disinfect the water.

Chlorination

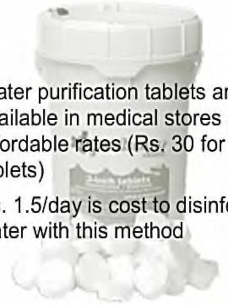
To disinfect water and remove bacteria and viruses from drinking water

- Low SEC settlements mainly depend on groundwater source for daily water requirements
- Water is directly collected from source and used in drinking and cooking purposes
- Water logging is commonly observed at common water sources
- Poor water quality with pathogenic contamination is common in poor settlements
- Safe water handling (filling and transportation) is not practiced in low SEC settlement due to lack of awareness that increases chances of water contamination
- This increase health risk and subsequently expenditure on health for poor families
- Chlorine treatment can be used as one of the option to disinfect drinking water

Benefits

1. Method is simple, inexpensive and reliable
2. Effectively kills bacteria and viruses present in water
3. Chlorine tablets are readily available in medical stores
4. Boiling of water is not required. This saves energy resource (gas, kerosene, other fuel) that can be used for other purposes like cooking for longer time
5. Easy to understand by people with limited training
6. Reduce medical expenditure
7. After chlorine treatment, residual chlorine in water further protects it against re-contamination

Cost



- Water purification tablets are available in medical stores at affordable rates (Rs. 30 for 50 tablets)
- Rs. 1.5/day is cost to disinfect water with this method

Usage

1. Directions of usage are given in local language as well as English on packet containing tablets
2. Most of the brands recommend to add one chlorine tablet to treat 10 liters of drinking water
3. 10 liter of water is equivalent to one water filling utensil "Handa/Ghada" used in kitchen
4. After adding chlorine tablet in water, mixing is allowed to dissolve up to 30 minutes. After that water is ready for drinking usage
5. 1 liter of chlorine can treat 10,000 liters of water. Therefore, for disinfecting large size storage tanks, accordingly the proportion should be used (e.g. For 2,000 liter tank 200 ml of chlorine can be used to disinfect water)

Prerequisites

1. Before adding chlorine tablets, water should be filtered with clean cloth to remove suspended particles
2. Expiry date and usage should be checked on the packet containing tablets
3. Tablets should be preserved in safe place and should be kept away from reach of children.
4. Numbers of tablets to add in water for treatment varies for as per the strengths of tablets. This is written on packets and must be confirmed before usage

Constraints

1. Taste of water may not be acceptable to some users after chlorine treatment
2. The method is effective for disinfection of water and not for purification
3. Water is required to be purified before this treatment. People may avoid this step and treatment may not be effective.

TARU

Decentralized waste water recycling

With urbanization and changing lifestyles, the volume of wastewater generated in the urban areas is large and continues to grow. The wastewater collection efficiency in most of the urban centres in India ranges between 30% (CPCB, 2009) to 65% (NIUA, 2005). Main challenges for centralized wastewater treatment is large land requirement and high energy demands, while the potential users may be located far off from the plant. Transportation of large quantities of treated water from the centralized recycling plants to service regions (*gardens, irrigation and construction*) is not feasible due to costs constraints. As result, many of the plants are not able to meet their O&M costs and work at less than optimal capacity and only discharge the treated water in the environment without its usage.

On the other hand, the sewerage networks in most cities are either dilapidated in the core areas and coverage is poor or non-existent in peri-urban areas. Most of Indian cities do not have fully laid out storm water drainage system, or wherever it exists, it is not fully functional. As a result, mixing of sewage and storm water drainage is common and the mixed water finds its way to natural water bodies increasing risk of pollution of local water bodies and natural drainage. The sewerage system gets blocked with silt and solid wastes from runoff.

Waste water is more efficiently treated near the point of demand and can be used for irrigation of gardens as well as for flushing and such system are feasible only at local levels. Such constraints can only be overcome by introduction of decentralized wastewater treatment systems starting from settlement levels. However, one of the major constraints is of land requirement. Innovative solutions are necessary in urban environments where land values are very high. Parks, small roads/paths and other common lands can be effectively used if most part of the treatment is done underground, but enabling land use rules are necessary.

The demand for reliable, efficient and low cost wastewater treatment system is increasing worldwide especially in densely populated urban environments where adequate wastewater treatment systems do not exist and uncontrolled discharge of wastewater endangers environmental health and water resources. In most of the developing countries, wastewater is partly treated or waste water is directly discharged into a river or lakes, which farmers downstream often divert for irrigation (vegetables and fruits). This imposes health risk to consumers of these products.

Daily wastewater generated from 1,000 households settlements of various SEC are estimated considering 80% waste from consumption. Wastewater discharged from the middle and high SEC are almost two to three times higher respectively from the lower SEC households..

Most communities use fresh/clean water (high quality) for most of the activities requiring low quality water. Flushing, gardening, and construction are two activities that can use low quality water. Water scarcity during summers is so acute that bans are imposed on construction activities in peak summers in many cities of India. This affects livelihoods of construction workers.

Decentralized Wastewater Treatment Systems (DEWATS)

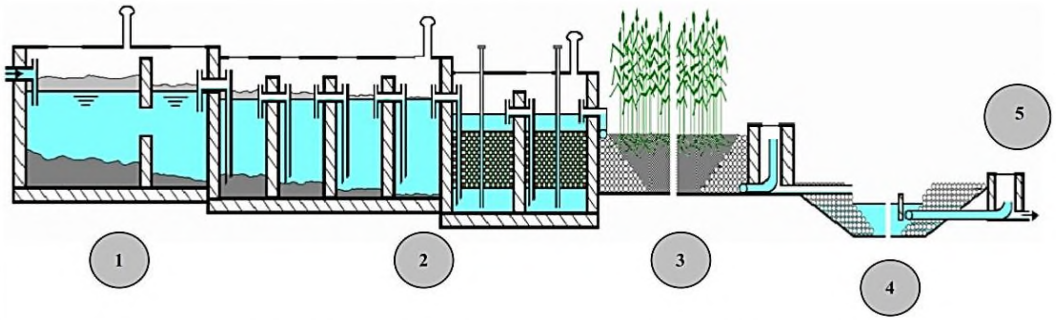
Increasing water demand and dependency on costly imported water are important concerns in growing urban centers. About 80% of water is discharged as waste water (gray water and black water) from daily domestic usages. High quality water is used in low end usages like flushing, floor cleaning, car washing and gardening. These requirements can be easily fulfilled with recycled water from DEWATS.

Comparison of DEWATS with sewer system

1. Requires limited convey mode (piping) for waste water in DEWATS system, hence cost of laying long pipelines is reduced.
2. Sewer system (piping assembly) is located at shallow depth therefore easy to handle/locate during maintenance.
3. Gravity flow (natural slope) can be maintained due to small coverage area of the system.
4. In case of failures, affects limited area instead entire area
5. Routine Operation & Maintenance does not involve skilled staff and high costs

DEWATS is independent natural process of cleaning waste water and bring it back in reusable state. Waste water from households passes through processes in septic tank, anaerobic reaction chambers, planted gravel filter bed and finally from polishing pond of DEWATS. The treated water is collected in storage tanks for low end usage purposes. In each process stage, waste water quality improves with reduction in BOD and COD of polluted water. With proper designs DEWATS can treat 1,000 to 150,000 liters of waste water in a day.

DEWATS System



1-Septic Tank; 2- Reaction Chambers; 3- Gravel Filter; 4-Polishing Pond; 5- Recycled Water

Benefits

1. Low quality water requirements for flushing, washing, floor cleaning and gardening that does not require high quality water can be fulfilled with recycled water
2. Affordable capital cost and low operation & maintenance cost when adopted at community scale
3. Underground construction therefore optimum usage of space
4. Residual sludge can be used to produce bio-gas
5. Saving of high quality groundwater that is used in gardening or irrigation purposes

Adaptation Scale

1. More successful at community scale due to high cost of infrastructure development
2. Large quantity of waste water from domestic consumption can be recycled by collecting in community septic tank
3. Operation and maintenance cost distributed among households ant thus economical
4. Community gardens can be maintained with recycled water

Prerequisites

1. Willingness of community to take ownership of the system for sustainability
2. Land in community that is legally in the possession of community group to construct the system
3. The space required is about 1,000 to 1,500 up to 50KLPD system
4. Efficient sewer system to convey waste water from households to plant site

Constraints

1. Internal conflicts among various groups in community
2. Preparedness of community for fund for capital and O & M cost
3. Yearly sludge cleaning is required for desired output
4. Planted gravel filter cleaning required after every three years
5. Easy acceptance of treated water in daily low end usage by people
6. Retrofitting of piping infrastructure in developed community to make maximum use of recycled water
7. Sustained interest of people to maintain the system
8. For the recycled water to be used in construction activity, raw water should possess lower concentration of Chlorides and Sulphates so that the recycled water meets requirements for construction purposes.

Cost

Capital Cost:
Capital cost for DEWATS varies as per geographical location, capacity of plant to recycle waste water. In good quality soil, with low groundwater level and minimum free board following cost is expected. The capital cost reduces for large quantity treatment systems.

Plant Capacity (Cum)		Cost (Rs./cum)	
Min.	Max.	Min.	Max.
10	30	50,000	65,000
30	80	40,000	60,000
-	>80	30,000	40,000

Ref: Center for DEWATS Dissemination: Guide on DEWATS

Maintenance Cost: Approximately Rs. 8,000 including salary of caretaker, sludge removal (once in two year) & cleaning of filter material (after three years).

Treated water quality

Quality of recycled waste water should fulfill standards set by pollution control board for full body contact requirements and irrigation purpose.

The quality of treated waste water should meet following criteria

- pH :- 6.5 to 8.5
- BOD:- 3mg/l (5dyas time @ 20°C)
- Total Coli form: <500MPN/100 ml
- Dissolved Oxygen: 5mg/l

TARU

Slow Sand Filter System

Purpose

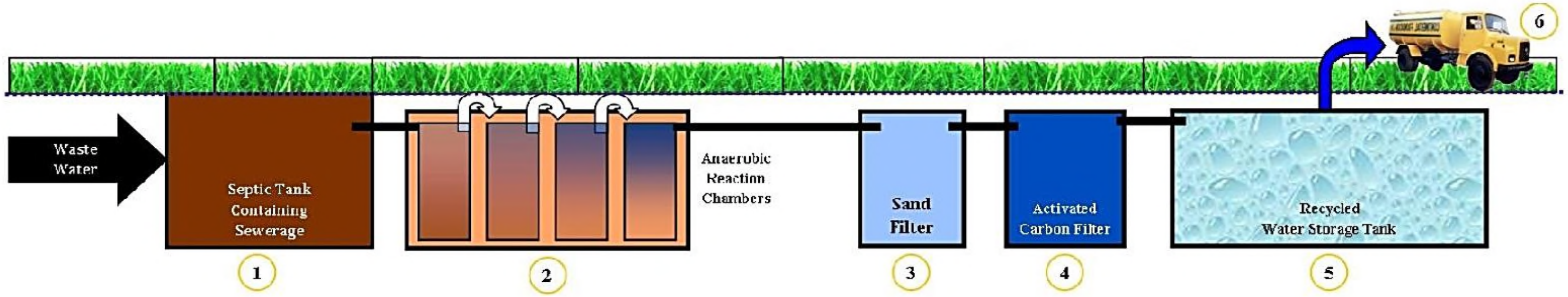
- To convert waste water into useful resource for low quality requirements (flushing, washing, gardening, irrigation)
- To prevent groundwater over exploitation by providing supplementary resources for usage in irrigation and construction purposes

Process

It works through the formation of bio-film called *Schmutzdecke* in the top few millimeters of the fine sand layer. This layer consists of *bacteria, fungi, protozoa, rotifera* larvae. As a *Schmutzdecke* ages, more larvae tend to develop. The Schmutzdecke layer provides effective purification in water treatment, by disintegration of sewages. Underlying sand acts as support medium for biological treatment layer. As water passes through the *Schmutzdecke* particles of foreign matter are trapped in the mucilaginous matrix and dissolved organic material is absorbed and metabolized by the *bacteria, fungi and protozoa*. Particles, as small as 2 microns are trapped in the hypogeal layer. The water produced from a well managed system can be of exceptionally good quality with no detectable bacteria content.

Following are stages in slow sand filter method:

1. Sedimentation in septic tank
2. Anaerobic Reaction
3. Filtration
4. Activated Carbon Filter
5. Collection of Recycled Water
6. Distribution (tankers/pipelines)



TARU

Cost

SN	Particular	Cost (Rs.)
1	Civil Work :	13,80,000
	RCC Tanks including Septic Tank, Room & Brick Chambers	
2	Structural Designing :	60,000
3	Materials (mechanical) :	7,00,000
4	Labour :	2,00,000
5	STP Designing (Hydraulics)	60,000
6	Execution, Supervision & Process Activation	1,50,000
	Total	**25,50,000**

Maintenance cost

Estimated monthly O & M Cost	Cost (Rs.)
Gardener/Operator salary	3,000
Energy Cost @ Rs.5/unit for 6 running hrs/ day	3,500
Minor Repairs towards operation	500
Back flushing of system (monthly converted)	1,000
Carbon filter replacement costs (monthly converted)	5,000
Total	**13,000**

Capital and O&M cost shown above are based on quotation received for construction of 50KLPD capacity waste water recycling plant in CWM project under ACCCRN program in Indore

Treated water quality

pH- 67
TDS- <2000 ppm
TSS<100
BOD< 30 mg/l
COD<250 mg/l
Total Coliform <500 MPN/100 ml

Operation & Maintenance

1. Easy to operate. Does not require higher skills to operate.
2. Yearly back flushing of system is required to remove clogging in the sand
3. Activated Carbon filter media to be changed every fiver years

Benefits

1. The system is more robust compared to DEWATS.
2. Various modules of the system can arranged as per availability of space
3. No foul smell surrounding plant
4. The plant and weed removal is not required in this method
5. Sludge formation is very slow in this method. It is required to remove after fiver years
6. There are no chemicals used in this system
7. Water can be used for irrigation and construction purposes

Constraints

Compared to DEWATS system energy requirements are high in this technology
Clogging of sand reduces the running efficiency of the plant

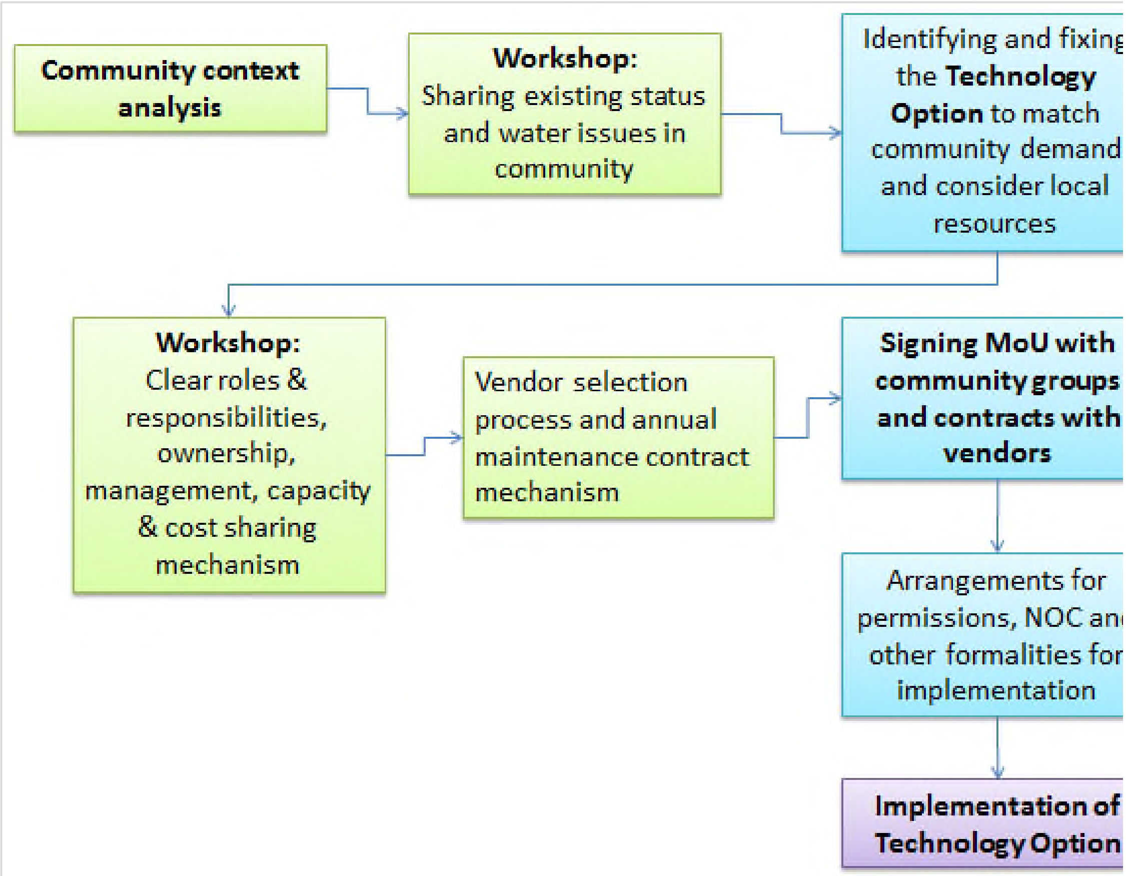
TARU

The Community Engagement Process

5 The community engagement process

It is necessary to engage the use communities right from the community context analysis stage to ensure sustainability of interventions. This is important to ensure that they understand the issues beyond household levels, indirect impacts of water scarcity and to develop sense of ownership among them. The community engagement process is described below:

Figure 25: Community engagement process



Source: TARU, 2012

In the CWM project of Indore, India under ACCCRN program; the following approach was adopted to implement community and household level implementation. While household level implementation requires an agreement of single family, the community level implementation demands a more systematic approach. To implement the selected interventions following steps were followed:

1. Reaching common consensus among people for the selected option
2. Risk analysis
3. Ownership confirmation by community institution through MOU
4. Demand creation by awareness campaigns, street plays, workshops, or other mode conveying the need and benefits of the option for the community
5. Capacity building to manage the system
6. Land permissions in the form of No Objection Certificate (NOC) from all stakeholders in case of common land (house/community groups)

7. Consultation of following departments for permissions
    a. Collector or Municipal Corporation offices
    b. Gram Panchayat office (local government in case village)
    c. Town & Country Planning Departments
    d. Pollution control department
    e. Electricity department

Risk analysis

Following are some of the risks involved in community level interventions. It is generic and indicative. It will vary as per the local context. Before implementation, risks should be identified and possible ways to deal with them should be worked out.

Table 18: List of possible risks in implementation with solutions

Possible Risks	Possible solution
Permission delays from the government offices	Immediate application after selecting suitable option. Background check on permission requirements and liaison with government offices beforehand.
Delay in fund contribution from community	Provide buffer period for collection Make alternative arrangements from other stakeholders. Improve mobilization methods
Delay in implementation with internal conflicts	Identify existing conflicts in advance during CCA. If conflicts exist, try to resolve through third party mediators with minimum direct involvement. If issues cannot be sorted out, wind up the intervention to reduce further risks later.
Lack of ownership towards intervention by community	Assess interest through beneficiary contribution. Provision in MoU to discontinue the benefits from option to community Identification of other beneficiaries Provision in MoU to shift infrastructure in other needy community if possible
Performance of implementation not up to the mark	Intense community mobilization from beginning Develop strategies to increase demand
Dominancy by single leadership or group in community	Create committee and distribute roles and responsibilities to more people in community

Source: TARU 2012

It is suggested that risk analysis is conducted well in advance and in close coordination with the user community and ULB. Also, it is necessary to review the risk assumptions and develop strategies to address fresh risks, if any, during the course of the intervention. Context specific risk analysis has to be done by the implementation team. It is suggested that the local civil society groups are involved right from the beginning to build a greater level of ownership.

Implementation process

6 Implementation process

Any community level implementation stage is taken up only after community (all residents) have agreed to accept the intervention and are willing to own the assets by contributing part of the costs by cash or in kind. For the sustainability of the interventions, a community level committee should be formed and empowered to take its ownership.

6.1 Management Committee:

A management committee should be formed that would take ownership of assets created. The committee will be responsible to complete the project as well as manage it post completion. Their responsibilities can include: Fund collection from community, seeking permission from government offices for interventions (e.g. land, electricity), facilitating agencies involved in project implementation and O&M responsibilities. Motivation and capacity building should be done, especially in informal settlements. Existing community groups can be used wherever feasible.

6.2 Memorandum of Understanding:

Working out clear roles and responsibilities expected from the community group and the agency involved (NGO) in project development is necessary. This can be done through Memorandum of Understanding (MoU) with the community group. The MOU should be preferably a legal document and should contain following clauses.

a. Definition of roles and responsibilities
b. Phasing of contribution for community
c. Logistic support
d. Operation and maintenance responsibility
e. User fee fixation and collection system

6.3 Contracting process:

All bidding and contracting process should be transparent and the management committee should be engaged in bidding process. Contract agreements are required with the vendors and contractors hired to implement the project. Clear timelines to complete the implementation should be mentioned in the contract. The community committee should be informed and consulted as and when required for this.

6.4 Annual maintenance contracts:

Community managed water related interventions especially in low SEC communities do not often succeed due to complex O&M and precautions required to manage equipment like RO plant. Annual maintenance contract with the vendor is better way to manage the complex operations like preventive maintenance, repairs.

6.5 Staff training:

Selection of local operators should be based on education and skill levels. These operators should be trained about routine operations and work only as per standard operating procedures laid out. They should be discouraged to carry out any repairs by themselves.

6.6 Operating procedures and safety:

Standard operating procedures should be laid out to manage the system and also to handle emergencies. Training on use of safety equipment as well as precautions are necessary.

6.7 User fee fixation and collection systems:

The user fee should be worked out based on following costs:

a. Monthly maintenance cost (Staff, Electricity, Consumables, AMC)
b. Long term maintenance cost. This can be converted to monthly costs
c. Repayment period of capital cost
d. Inflation in rates for the energy & fuel, consumables

6.8 Financial management:

Monthly budget should be calculated before the beginning of each month and it should be followed strictly. Monthly or weekly coupon system can be used to manage user fee collection to avoid hassles. A bank account should be opened and all user fee collection is preferably be deposited by the end of the day.

6.9 Monitoring, Grievance redressal:

Water related interventions require periodical monitoring for assuring quality of water delivered by the system. The quality criteria must meet the national standards. Regular water quality monitoring from government approved laboratories should be done. Also a complaint and redressal system should be in place before the water is supplied. A conflict resolution mechanism should also be laid down.

6.10 Exit strategy:

A clear exit strategy should be worked out and informed to the Management committee before the implementation is taken up. The responsibilities of staff and committee should be slowly increased over the project duration to enable them to handle the assets and finance by themselves over the project period.

Ways forward

7 Ways forward

In a business as usual scenario, the urban water crisis is expected to grow and climate change is likely to amplify the scarcity and introduce additional uncertainty in water availability. The poor are likely to face the brunt of the scarcity, since they are the last to get access. A variety of measures would be necessary including reducing the demand, improving supplies, water quality management, wastewater recycling at various scales. This would require information, incentives and regulatory interventions as well as involvement of multiple stakeholders. Also, technical support in designing, implementation and maintenance support would be required for the decentralised urban water management to take root.

The water resource development and management in India lies under the state government preview. Urban local bodies have been empowered to plan, develop and manage the water resources under the 74th constitutional amendment. There is a need for addressing urban water issues beyond centralised water supply and sewerage systems. The following interventions would be first step to bring a paradigm shift in addressing urban water issues.

7.1 Water management:

Water in all forms should be managed together. A city water budget should be implemented and updated every year. A GIS based water use monitoring and management systems should be implemented, which can include:

- Water supply, sewerage and storm water drainage system
- Traditional water bodies & other assets
- Ward-wise consumption & recycling
- Water balance of surface & groundwater
- Pollution status across wards
- Groundwater

A part of this GIS can be made available to public to create awareness and manage water better. An incentive system can be implemented including prize for the best performing ward/township based on fixed criteria.

7.2 Demand focussed end use:

The ULBs maintain large gardens as well as lakes within city limits, Water scarcity as well as use of treated water is being done for irrigation as well as other low end use for flushing in large public buildings. ULBs can demonstrate decentralised waste water treatment technologies in these gardens and large buildings to reduce pressure on drinking water and reduce groundwater use. These demonstration units would underline the seriousness of the ULBs and also create interest among the communities and townships.

7.3 Groundwater management:

The existing rules and regulation framework for the groundwater source usage needs to be strengthened. Most states have established a Groundwater authority, but they have limited staff and powers. Drilling of new bore wells by private parties requires permissions, and they should be strengthened by:

- Ward level monitoring of groundwater water levels as well as quality
- Registration of all old as well as new bore wells
- Estimation of withdrawal at settlement levels
- Surface and groundwater Monitoring systems
- E-governance based permission granting system based on defined criteria

7.4 Land use and building bye laws:

In the country, decentralized waste water recycling is slowly getting the momentum. However, the existing land uses policies that do not allow the construction of such plants in community gardens prevents adaptation of such options. New building bylaws have provisions for rainwater harvesting structures, and they should be extended to include decentralised sewage treatment plants and other structures. A clear incentive-disincentive system should be laid out to encourage old settlements also to install decentralised wastewater management systems.

7.5 Land rules:

Considering the limited spaces, high costs involved in complete underground construction of various modules of decentralized STPs; relaxation for construction of part of the waste water treatment systems above ground in land use laws are necessary.

7.6 Water management in peri-urban areas:

The peri-urban areas are managed by Panchayats. They do not have capacity to manage water. The ULBs and groundwater authority should provide technical and monitoring support and also lay down rules for use of water for various end uses. The rainwater harvesting and decentralised waste water treatment rules should be implemented in these areas.

7.7 Citizen involvement:

The citizen groups are active in many cities, but concerted efforts are necessary to promote decentralised water management at household and community levels. Citizen groups can take proactive steps by involving in promotion, monitoring and advocacy efforts.

7.8 Private sector engagement:

Design, implementation and management of decentralised water management systems cannot be done by the ULBs. While the ULBs should monitor and regulate water use, small and medium enterprises are required to provide support in design, implementation and maintenance support to communities. Training of architects, engineers at one end and plumbers, masons and mechanics is necessary for implementation and management of decentralised water systems.

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Annexure

Annexure 1: Sample questionnaire for socio-economic surveys

TABLE NO. 1
SETTLEMENT, KINSHIP AND EDUCATION DETAILES

[1] Community: ____________________ [2] Date: __________ [3] Name of Organization: ____________________

[4] Name of Surveyor: ____________________[5] GPS Instrument: ____________________

Instructions: 1. Write an answer applicable from given options 2. Please look the attached sheet for the abbreviations used

Settlement details								Kinship Details				Education Details					
Polygon. No.	**HH Detail**	**Name of respondent**	**House type**	**No. of floors**	**Roof type**	**Ownership**	**Mode of use**	**Native place**	**No. of years in the community**	**Religion**	**Total Family Members**	**PG**	**G**	**>10**	**<10**	**No. Of Children not going to school**	**Illiterates**
			Sa, App Rh, Kc In	G, 1,2,3	*Cem, RCC Ct, Mp Tn*	*Ow, Rt,*	*Rs, Mx, Cm In*	*N, OMP U, Mh Bh, Cg, other (mention)*		*Hn, Ms Sk, Cr, Tr*							

ABBREVATIONS USED

House type	No. of floors	Roof type	Ownership	Mode of use	Native place	Religion
Sa-_standalone_ ***App***_-Apartment_ ***Rh***_-Row house_ ***Kc-*** _Kaccha_ ***In***_- Informal House_	***G- Ground Floor*** ***1- First floor*** ***2- Second floor*** ***3- Third floor***	***Cem***_-Cement Sheet,_ ***RCC-*** _Reinforced Cement Concrete_ ***Ct***_- Country type tiles_ ***Mp***_- Mangalore pattern tiles_ ***Tn***_- Tin Sheet_ ***RCC+Tn***_- RCC for Ground floor and Tin on first floor_	***Ow***_-Owned_ ***Rt***_-Rented_	***Rs***_-Residential_ ***Mx***_-Mixed_ ***Cm***_-Commercial_ ***In***_-Institutional_	***N- MP*** _<250 km_ ***OMP***_-Other parts of MP_ ***UP-*** _Uttar pradesh_ ***Mh-*** _Maharashtra_ ***Bh***_- Bihar_ ***Cg-*** _Chhattisgarh_	***Hn***_- Hindu_ ***Ms***_-Muslim_ ***Sk***_- Sikh_ ***Cr***_- Christian_ ***Tr-*** _Tribal People_

1

TABLE NO. 2 Occupational Details											
Polygon No.	**HH Detail**	**Total earning members**	**No. of Working women**	**Govt. Class I&II**	**Govt. Class III&IV**	**Pvt. service Professional**	**Pvt Service support staff**	**Business large and medium**	**Petty business**	**Informal skilled**	**Informal unskilled**

2

Annexure 2: Sample water infrastructure assessment questionnaire for household and community level surveys

Table 1: Water Supply & Infrastructure Details

Sr No.	Polygon No.	HH Detail	GPS	**Water Dependency** Groundwater (GW), Narmada Pipe (Np), GW + Np, Tanker Supply*	**Groundwater Source ***	**Water Supply Time (24 Hr. Format)**	**Daily-D Alternate Day-AD Other- specify No. of Days**	**Supply Duration (Minutes)**	**Persons involved in water collection**		**If children collecting water**			**Monthly Expenditure on Water (Rs.)**		**Storage Capacity Details** UGT- Underground Tank, OHT- Overhead Tank										
			Note GPS Point No.	*Use Tanker Supply table	*Use Bw table	After 12 PM Use 13, 14, 15 etc.	Supply Interval		No.	Hrs. spent	No.	Year	Hrs. spent	Bill	Maintenance	**UGT**	**Lit.**	**OHT**	**Lit.**	**Drums No.**	**Drums Total Lit.**	**Utensils No.**	**Utensils Lit.**	**Common Govt. Facility (like Sintext tank, Cement tank etc.)**	**Govt. Lit.**
					Write B1.B2 OR P1,P2 B-Bore well P-Pvt. Bw							Age				Yes/ No		Yes/ No							
1																									
2																									
3																									
4																									
5																									
6																									
7																									
8																									
9																									
10																									

Table 2: Tanker Supply Details

Sr. No.	Polygon No.	HH Detail	Tanker Requirement	Frequency	Tanker Capacity	Provided By	Cost (Rs.)	Is Cost Shared?	No. of HH Sharing
			Seasonal (S), Regular (R)	No. of times required in Month	Liters	IMC/Pvt.	Per tanker, if answer is Yes	Yes (Y), No (N)	Mention Number
			S/R					Y/N	
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

Table 4: Stand Post Detail (Related with BW table**)**

Sr. No	Point No	Source	Supply Day	No. of Taps	Water Color	Water Taste	Water Smell	No. of HHs covered	Storage if any at the location with capacity	Platform	Drainage channel, if any	Remarks
.	S1,S2	Narmada Piped supply, Bore Well (B1, B2..)	Every day, Two days, Three Days, Uncertain	1/2/3/4/..	Transparent, or Mention color N- No color R-Reddish M- Muddy	N-None, S-sweet, H-hard, O- Oily	Mention specific smell reported F- Fishy M-Metallic S- Sever like C-chemical (Any)	Number	Type: C-Cement, S- Syntax with capacity in liters	Cemented, None. Broken etc.	Muddy, Cemented	
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

R.O. Plant

Storage Tank (Individual Level)

Roof top Rainwater Harvesting

Storage Tank (Community Level)

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