Chapter 15

Developing integrated management plans for natural treatment systems in urbanised areas – case studies from Hyderabad and Chennai

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15.1 INTRODUCTION

Many natural water systems in India are contaminated due to uncontrolled discharges from cities and industries (CPCB, 2009). As a consequence, hydrological cycles are impacted to varying degrees, and the biggest impact is on potable water sources as well as irrigation waters for food production. The problems are most acute in the urban and peri-urban settings where development is rapid, and combined with water scarcity issues there is a need to look at how to prevent as well as treat and reuse used water for potable as well as non-potable uses. The projected water demand for a rising population will exert more pressure on the natural water supplies, therefore, it is important to treat contaminated waters and explore its safe reuse, especially where water scarcity is experienced. While multiple treatment technologies exist, not all are suitable for a given setting. The nature of treatment will depend on the source and reuse options, therefore, assessment of levels of contamination and the treatment strategy is an important consideration. Of the many technologies that are used for treatment of contaminants, natural treatment systems (NTS) are quite common and cost-effective and are being used world over with considerable success (Arceivala & Asolekar, 2006; Reed *et al*., 1995; Shipin *et al*., 2005; Crites *et al*., 2014).

Existing NTS can play an important role in contaminant attenuation, enhancing its potential use and address the water scarcity issues in a country like India. The natural treatment processes are simple, and offer treatment of polluted waters through a combination of natural soil aquifer processes and plant-root systems (Nema *et al*., 2001; Kaldec & Wallace, 2009). NTS like soil aquifer treatment (SAT), Managed Aquifer Recharge (MAR) or constructed wetlands (CW) are robust barriers, that can remove multiple contaminants, minimise the use of chemicals, use relatively low energy and have a small carbon footprint (Sharma *et al*., 2008; Zurita *et al*., 2009; Missimer *et al*., 2014), and utilise locally available resources. These systems have been applied for wastewater treatment (as pre-treatment, main treatment or post-treatment) and reused in multiple ways (Sharma *et al*., 2011).

Thus, the NTS can offer cost-effective means of treating contaminated water and can be integrated into the urban water management cycle to cope with different needs in and around the cities. However, when treated wastewater is integrated into an urban water management cycle, a number of issues have to be considered. Human health, environment, economic and social considerations are some of them. City sanitation plans (CTPs) are geared to address the sanitation related issues and can shed some light on how existing integrated management plans work within the cities. This paper describes a framework for introducing NTS as part of urban water management cycle, addresses some of key issues through the sanitation lens, and discusses how integrated management plans can help relieve some of the pressures of freshwater needs for the cities. The concept is introduced using two case studies from Hyderabad and Chennai, respectively, where NTS have proved to be a useful method for treating water in urban and peri-urban settings, and where the treated water has reuse potential in agriculture and aquifer recharge.

15.2 NATURAL TREATMENT SYSTEMS IN INDIA

A national survey of NTS identified over 108 sites that have operational systems for treatment of water to varying degrees (see Chapter 8). The study showed that most of the operating systems of the NTS were enhanced by the addition of mechanical pre-treatment for the removal of gross solids, especially where sufficient land suitable for the purpose is available. Further, it was observed that these options were cost effective in terms of both construction and operation especially in the urban areas. The operation and maintenance of these systems were managed by communities who were users or agencies, and the involvement was either direct or indirect and included collection, treatment and disposal. The primary aim of the agencies was to improve the sanitation facilities as well as to safeguard human health. Some of the types of examples are hyacinth and duckweed ponds, lemna ponds, fish ponds, waste stabilisation ponds, oxidation ponds and lagoons, algal bacterial ponds, and polishing ponds of Wastewater Treatment Plants (WWTPs). Of these, the most common system was the waste stabilisation pond which accounted for nearly 73% of the cases.

In India, only 37% of the wastewater generated in Class I and II cities and towns is treated (CPCB, 2009). Where the inadequate network coverage is attributed to the poor state of sanitation, there is ample opportunity to set up NTS as decentralised systems to lessen the burden on the larger network systems. It is known that natural water bodies will vary in response to environmental conditions. Therefore, it is important to understand how the systems function in nature, which in turn helps to identify the treatment potential and the fate of contaminants. Once the mode of contaminant removal is identified, it can be engineered to enhance its functions, and become part of a large scale wastewater treatment system. However, this requires a good assessment of the source water, and a well-defined management plan, for collection, treatment and final disposal to the environment. This will help free up the fresh water supplies needed for domestic purposes, and support the reuse of treated water for non-potable uses. Such a plan can also help network the small-scale businesses and illegal connections, and reduce the indiscriminate discharge to the environment that leads to pollution. While the construction aspects are relatively easy to deal with, its sustainable management requires a good plan that involves the communities and the responsible stakeholders. When such an alternative water supply is added to a total water management plan of a city, the largest beneficiaries of the treated water will be the industry, agriculture and city landscapers. NTS, can be cost effective and can be modelled to suit a setting, which is manageable and involves communities or public-private partnerships for sustainable solutions. Further, it helps environmental experts and policy makers to define legislation with the intention that the water is supplied and maintained at an appropriate quality for its identified use.

15.3 POLLUTION REDUCTION – CITY SANITATION PLANS

Sanitation policies, guidelines and regulatory processes are aimed at improving public health and environmental outcomes. In particular, these help to reduce pollution of water sources and indiscriminate dumping of waste in unauthorised places. The water safety plan, wastewater discharge standards and National Urban Sanitation Policy, which are designed to achieve sanitation targets, provide the necessary backdrop to develop the CSPs. Country-wide coverage has been effected by a directive given by the Ministry of Urban Development in India (MoUD, 2008). The requisite guidelines are given in its policy and sets out the overall strategy to address the proper sanitary disposal of all types of waste and behavioural attitudes of people. Thus, a CSP outlines the strategy of a city to achieve total sanitation status, which encompasses many elements as given in Figure 15.1. For example, a CSP demands multistakeholder participation, public consultation, baseline data collection and sanitation mapping, awareness raising, suitable technology selection and adoption, capacity building and monitoring and evaluation. Institutions like the Administrative Staff College of India (ASCI, n.d) has helped to develop a number of CSPs, where cities have lacked the capacity. It is expected that such a plan would transform urban India to meet international standards of healthy living, enhance tourism for revenue generation, and also improve the health and hygiene standards of people. Cities and towns have been requested to develop CSPs, addressing the technical and non-technical aspects of sanitation services delivery. However, the development of CSPs have not taken off as expected, reflecting in some ways the lack of capacity and training in the relevant institutions that are expected to take on the responsibility. The framework for CSPs demands a good knowledge on urban planning, sanitation, technical infrastructure and financing as well as to cater to the needs of local communities. Participatory development of CSPs is recommended, as planning for sanitation infrastructure alone cannot meet the requirement of achieving a high sanitation status. Further, in the implementation, the cities have to incur capital investments, adjustments of bylaws, strengthen administrative structures and develop capacity for sustainable management.

Thus, the CSPs address both technical and non-technical strategies, which include, the domestic water supply, solid waste management and drainage systems for disposal (MoUD, 2008; WSP, 2010). A gamut of non-technical aspects include policies and regulations, enhancement of institutional capacity, finances, community awareness and participation, private sector engagement, NGO engagement, and monitoring and evaluation. While Hyderabad is yet to develop a CSP, at the state level some guidelines have been established after discussion. The target areas for consideration are water supply (all types of

sources, treatment to drinking water standards and distribution), solid waste management, wastewater collection and disposal, and storm water drainage. Further, an overview of the state level sanitation – current situation and challenges – achieving sanitation rankings for the cities in the state (National Award Scheme for Sanitation for Indian Cities, *The Nirmal Shahar Puraskar* – Press Information Bureau, Government of India, 2010), securing funds for sustainable sanitation activities has also been considered.

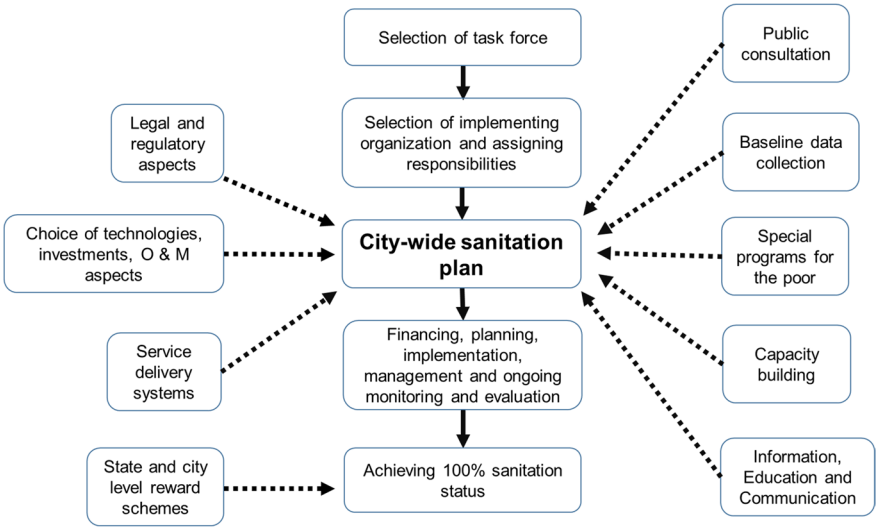

Figure 15.1 Key elements of a City Sanitation Plan (adapted from MoUD, 2008).

It appears that cities and Urban Local Bodies (ULBs) can be well endowed with grants under the 13th Finance Commission recommendations and further enhanced by schemes such as the Jawaharlal Nehru National Urban Renewal Mission, Urban Infrastructure Scheme for Small and Medium Towns, Infrastructure Development Scheme for Satellite Towns, North Eastern Region Urban Development Programme, Backward Region Grant Fund, multilateral and bilateral funds and significant initiatives by States themselves. However, such programs have not been fully utilised to achieve 100% sanitation status, and many cities still lag behind not being able to start up leave alone maintain. While the sanitation ratings were seen as a stimulus to engender change, its intended impact has not been fully achieved. The review on the CSPs show that adoption requires a good action plan, a dedicated set of staff, capacity building, community support, incentives for workers, and innovative ways to deal with each setting. In 2014, yet another program on sanitation was launched by the MoUD titled *Swachh Bharat Abhyan*, targeting 4,041 statutory towns, with objectives similar to that found in the CSPs (MoUD, n.d.). These are elimination of open defecation, eradication of manual scavenging, modern and scientific municipal solid waste management, bring about behavioural change to embrace healthy sanitation practices, awareness building on links between sanitation and public health, capacity augmentation for ULB's, and create an enabling environment for private sector participation in CAPEX (capital expenditure) and OPEX (operation and maintenance). In each state, a designated officer from the MoUD is appointed as the responsible officer to manage the program.

15.4 WATER SUPPLY AND SEWERAGE MANAGEMENT IN HYDERABAD AND CHENNAI

15.4.1 Hyderabad

City water supply

Hyderabad is the fourth most populous city in India with its 6.8 million people. With the recent bifurcation of the former state of Andhra Pradesh, it will serve as the capital for both states for a period of 10 years, after which it will be the capital city of Telangana (Figure 15.2). The city administration is governed by the Greater Hyderabad Municipal Corporation (GHMC), covering an area of 650 km^2. The Hyderabad Metropolitan Water Supply and Sewerage Board (HMWSSB) is responsible for the city water supply and wastewater management. Once dependant on lakes and reservoirs closer to the city, Hyderabad now lifts water from over 114 km to bring Krishna water to the city. This increasing demand has placed pressure on freshwater resources more than ever, and draws attention to the fact the freshwater sources should be protected as much as possible, while

treating wastewater for alternative uses. The division of the former state has brought in a separate issue to the forefront, which is sharing the source water from the Krishna river (TToI, 2014a). This places pressures on the city of Hyderabad to clean up some of the lakes and rivers within the state to provide drinking water for its citizens and also water for food production. However, most natural water bodies are polluted including the Musi River, which runs through the city carrying large volumes of wastewater (1.25 million m^3/d – both domestic and industrial) discharged from the city.

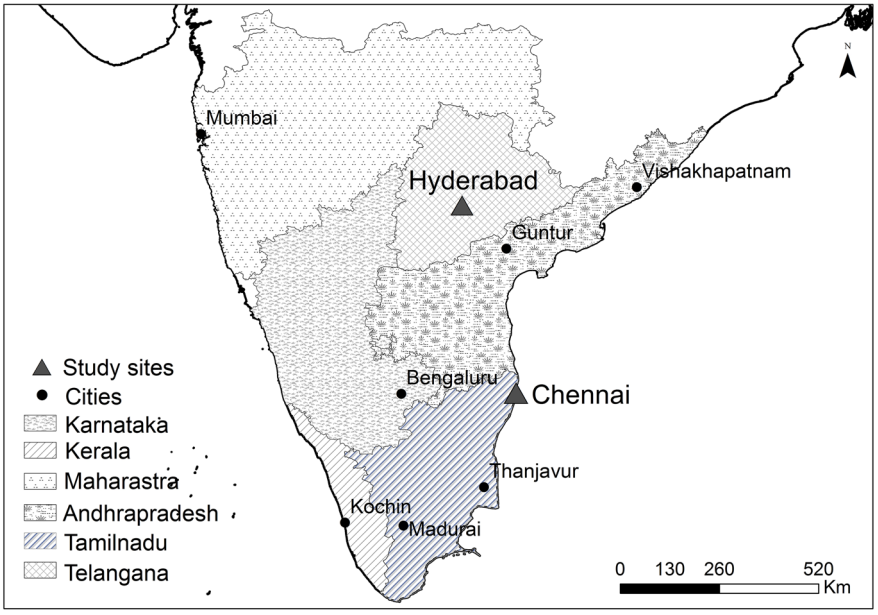

Figure 15.2 Study sites for natural treatment systems in the cities of Hyderabad (Telangana) and Chennai (Tamil Nadu) (Source: IWMI).

Hyderabad receives water from five sources (HMWSSB, 2013), which are Osmansagar on Musi River, Himayatsagar on Esau River, Manjira Barrage on Manjira River, Singur Dam on Manjira River and Krishna River Water (Figure 15.3). The chronology of abstractions from these sources span over the period 1920 to 2008. As against the demand of 2.18–2.27 million m^3/d, HMWSSB is presently supplying water to their full potential at 1.50–1.55 million m^3/d from all the five sources, and in some instances lifting water from a distance of 110 km (Krishna River). With around 0.68 million m^3/d water shortage and an additional demand of 20 per cent, water supply status is far from adequate. While the groundwater does cover the gap to a certain extent (an estimated 40% of the supply is said to be from groundwater), in the drier months the bore wells dry up, which increases the demand for fresh water supplies from HMWSSB (The New Times of India, 2014). The plans for lifting water from Krishna (phase III) and Godavari (Phase I), are underway at a cost of INR 33 per kL and INR 38 per kL respectively (1USD = INR 60). The highly subsidised domestic tariff (INR 26 per kL) indicates the huge gap between the expenditure and revenue of HMWSSB. The loss of revenue is attributed to leakages in old network systems, lack of metering for over 78% of the consumers, illegal connections and inability to issue new connections due to the defict in supply.

Wastewater management and treatment

The wastewater is collected via a sewerage network system and treated at three treatment plants (Table 15.1). The treatment plant at Attapur is yet to be commissioned. The network coverage for conveyance is estimated at only 60–70% therefore, only 52% of the wastewater is treated at these plants that are operational. The rest is discharged into waterways via 19 nalas which ultimately reach the Musi River. Thus, the Musi River, which runs through the city, receives both partially treated and untreated wastewater and immediately downstream it is used for agriculture. The safety concerns for food production are not addressed as farmers lift the water for irrigation and use it as a nutrient rich water supply. This water supply cannot only be easily treated via NTS to a level suitable for irrigation, it can also be used for other uses like gardening, washing cars to relieve the pressure on the domestic water supply. It can also help in improving the sanitation conditions in the city, if it is planned as part of the water supply and wastewater treatment systems.

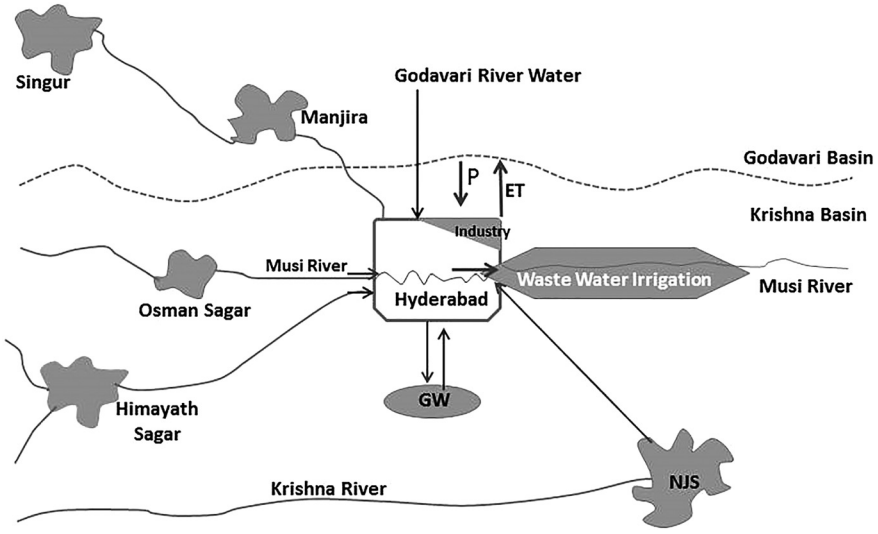

Figure 15.3 Drinking water supply to the city of Hyderabad. GW = groundwater, NJS = Nagarjuna Sagar Reservoir. (Source: Adapted from Van Rooijen *et al.*, 2005).

Table 15.1 Current wastewater treatment capacity of wastewater treatment plants and systems.

Description of Type and Site	Treatment Capacity [1000* m^3/d]
Wastewater (HMWSSB)[1]	
Amberpet	339
Nagole	172
Nallacheruvu	30
Attapur	51
Lakes (GHMC)[2]	
Hussain Sagar	20
Lakes (HMDA)[3]	
Patel Cheruvu	2.5
Pedda Cheruvu	10
Durgam Cheruvu	5
Mir Alam Cheruvu	10
Saroor Nagar Lake	2.5
Safil Guda Lake	0.6
LangarHouz Lake	1.2
Noor Mohammad Kunta	4
Ranghadhamini Lake	5
Treated wastewater	652.8
Untreated wastewater[4]	599.2

[1]HMWSSB – Hyderabad Metropolitan Water Supply and Sewerage Board.
[2]GHMC – Greater Hyderabad Municipal Corporation (2014).
[3]HMDA – Hyderabad Metropolitan Development Authority (2014).
[4]Wastewater generated is 80% of water supply to the city.

Wastewater drainage network system coverage in the core city area is estimated to be 80% and also over 30–40 years old (HMWSSB, 2013). Therefore, it is not sufficient to cater to the current wastewater flows. The peripheral city network coverage is about 30%, but new connections get added on periodically. The city needs about 1.3 million m^3/d wastewater

treatment capacity, but the existing treatment capacity is about 0.7 million m^3/d. The WWTPs depend on a water cess for its maintenance activities which is far from adequate. The high cost of urban land makes new construction very expensive.

Currently, the conventional WWTPs are capable of treating only 52% of the wastewater generated in Hyderabad city. The existing wastewater disposal systems include an underground sewerage system in the urban areas, septic tanks in suburban areas and pit systems in the peri-urban settings. HMWSSB is responsible for providing the services to the city people. Rehabilitation and new network connections are made with loan assistance (JICA) or state government funds. The National River Conservation Plan of the National River Conservation Directorate, Government of India, has been by far the largest contributor. Detailed project reports are prepared for specific activities to secure funding from the government. Models are being worked out to recycle the WWTP water, though at present the treated water is released back to the river. Continuous monitoring of water quality is now being carried out by the Central Pollution Control Board (CPCB, 2014).

Municipal solid waste management

The management and handling of the municipal solid waste in cities are governed by the Environment (Protection) Act, 1986 (29 of 1986), as prescribed in sections 3, 6 and 25, and detailed out as a set of rules, namely, "Municipal Solid Waste Rules 2000" which was gazetted in 2000. It stipulates that municipal authorities are responsible for the collection, storage, segregation, processing and disposal of Municipal Solid Waste (MoEF, 2000; CPCB, 2000). The regulatory authority for monitoring and evaluation is the Central Pollution Control Board (CPCB, n.d. *a)*. It has been estimated that a person living in Hyderabad produces, on average, 0.57 kg (2005) of waste per day (CPCB, n.d. *b*). For a projected population of nine million, the GHMC may have to deal with 5,181 tons of waste per day. The GHMC has introduced an integrated Solid Waste Management system through private sector participation, direct community involvement and effective public participation in segregation of recyclable waste. Local welfare associations and self-help groups play a major role in collecting waste, however, the bulk of the waste is collected and disposed of by a private company, Ramky Infrastructure Ltd. (REE, n.d.; TToI, 2013; TToI, 2014b). The landfill sites are 40 km away from the city, and the GHMC operates on BOOT/PPP (Build-own-operate-transfer/Public-private partnership) mode to dispose of the waste. A study that assessed the status of Municipal Solid Waste management in the country found that composting was the most popular method (Annepu, 2012). While the municipal solid waste collection has improved, it does not cover all parts of the city yet. Dumping in waterways still continues, a problem that might be seen for the foreseeable future.

City sanitation plan for Hyderabad

Currently, there is no CSP for Hyderabad, the reason for this is not clear. However, a state level plan has been outlined during a state level workshop. In general, a three tier approach has been suggested for better exchange of knowledge and experiences in sanitation issues. These are National Urban Sanitation Plan, State Sanitation Plan (SSP) and Urban Local Body (CSP-municipality/ULB) levels. The different components of the SSP are highlighted in Table 15.2.

Table 15.2 The activity plan for the state level sanitation plan.

Component 1	Component 2	Component 3
Support to central and state level urban sanitation program	Preparation and implementation of city sanitation plans (CSPs)	Knowledge management, communication and awareness raising
Management and planning instruments for the urban sanitation sector improved at central and state level	Support to develop CSPs, and enable municipalities to improve management skills, technical and financial aspects related to urban sanitation planning	All relevant stakeholders, (city authorities, community members, schools etc.) gain knowledge, and skills, improve communication related to urban sanitation

Source: APSSS & CSP (2013).

15.4.2 Chennai

City water supply

Chennai is one of the metro cities of India (Figure 15.2) in the State of Tamil Nadu, which relies on a system of reservoirs and lakes for its water supply. It is heavily dependent on the monsoon rains for recharging the water bodies, as three of the largest rivers within the state are heavily polluted. With a population of 4,681,087 (Census, 2011) the demand for domestic water supply has increased over time and as a consequence ground abstraction has increased, which has resulted in the decrease

of water levels in aquifers. Currently, the water needs of Chennai city are met by desalination plants at Nemelli and Minjur, aquifers in Neyveli, Minjur and Panchetty, Cauvery water from Veeranam Lake, Krishna River from Andhra Pradesh, Poondi reservoir, and Red Hills, Chembarambakkam and Cholavaram lakes (CMW, 2015; Mariappan, 2014). Figure 15.4 presents an overview of the different sources of water that the City Metro Water relies on to meet the increasing water demand. Since 2002 rain water harvesting has been mandatory, but the challenges have impeded the successful adoption of the practice. The lack of adequate awareness raising, education and guidance of the entire process were seen as the key reasons for poor uptake. As means to augment the water supply the government investment on desalination plants has also increased, which is not very well received by the environmentalists. The current water supply from all sources is 0.98 million m^3/d against a demand of 1.2 million m^3/d. The water supply to the city is managed by the Chennai Metro Water (CMW), which covers an area of 426 km^2. The state 12th Five Year Plan proposes an integrated urban water management plan, which takes into account a holistic approach of economic efficiency, social equity and evironmental sustainability, however, the city of Chennai is yet to implement such an integrated program. The key areas for consideration are explotation for alternative sources of water, alignment of formal and informal institutions and their practices, wastewater management and recycling, enhancement of water use efficiency and conservation practices, water sensitive urban planning, prevention of water source pollution, and utilisation of ecological sollutions for pollution control (Bahri, 2012).

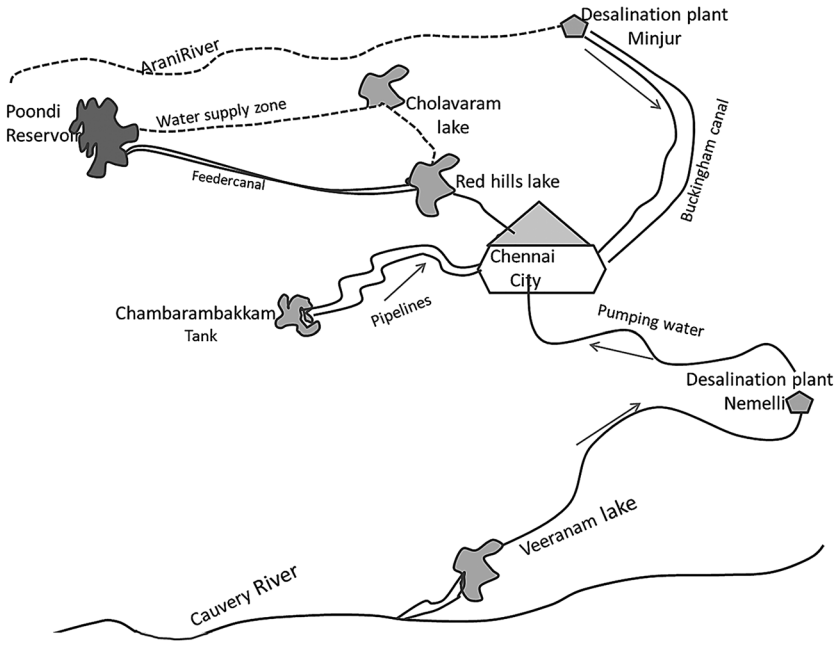

Figure 15.4 Urban water supply system in the city of Chennai. *Source*: IWMI.

Wastewater treatment and management

The Chennai City Wastewater System has been expanded over time to cater to the population increase. However, the sewerage network system is unable to handle the full flow, especially, when the storm water is released. The excess is drained into the natural waters close to the city viz. Cooum river, Adyar river, Buckingham canal and Otteri Nalla, which contributes to the large pollution loads in natural waterways and the drains. The following are the WWTPs of Chennai Metro Water Supply and Sewerage Board (CMWSSB) as at February 2014: Kodungaiyur 270 thousand m^3/d (110 + 80 + 80); Villivakkam 5 thousand m^3/d; Koyambedu 94 thousand m^3/d (34 + 60); Nesapakkam 117 thousand m^3/d (23 + 40 + 54); Perungudi 126 thousand m^3/d (54 + 60 + 12), totaling 612 thousand m^3/d of which 378 thousand m^3/d is powered by biogas (produced during the wastewater treatment) engines. To cope with the increasing population, the municipalities have been increasing the treatment capacity of existing treatment plants and the additions for each of the plants are stated in brackets. However, there is still a large treatment gap yet to be filled, which contributes to the overall pollution load in the waterways. It is felt that the city's inability to cope with treatment poses a great threat to the drinking water supply, especially in an area where the overflow pipes of septic tanks are connected to open drains and waterways.

City sanitation plan for Chennai

Like for Hyderabad, there is no sanitation plan for Chennai. While the national and state level guidelines are available, the activities have been planned in an ad hoc manner. In a recent report it was stated that on the national sanitation ranking Chennai received a score of 53% out of 100%. A study carried out on the sanitation services showed that the public sanitation services in the city were poor (IMRF-CDF, 2011). The key findings were that city public toilets were not adequate for the size of the population moving in the city, existing toilets were poorly maintained and underutilised, since city authorities did not have adequate funds for maintenance and governance. The 12th plan for the state of Tamil Nadu reports that sanitation coverage in the core areas of the city of Chennai is 99%. The CMWSSB is rensponsible for managing an estimated 610,000 network connections, 2,600 km of sewer lines and 180 pumping stations. The treatment capacity projected for 2020, is 1.49 million m^3/d, and highlights the capacity gap that has to be met in the coming years. The plan also highlights special programs for schools, solid waste management, and recycling of water in apartment buildings in the coming years (TNSPC, 2012).

15.5 CASE STUDIES

15.5.1 Natural wetland in the Musi River micro-watershed

A small wetland of the size of 4.5 ha, with a volume of standing water of 16,295 m^3, was studied for its function. The wetland was predominantly of *Typha capensis* grass with a submerged biomass of 18 kg/m^2 and a discharge rate of 1,812 m^3/d. The hydrogeological, geophysical and bio-geochemical investigations revealed that this wetland had potential to remove selected contaminants in its natural state (see Chapter 11). Natural systems both transform and capture many of the common pollutants that occur in domestic wastewater. These pollutants include nutrients like nitrogen (N) and sulphur (S), heavy metals, trace organic chemicals as well as disease causing pathogens, suspended sediments, and organic matter. The major natural processes occurring in natural systems include chemical adsorption (fixation), sedimentation (settling of solids), plant uptake, and bacterial degradation. This wetland, which is situated in the midst of rice, paragrass and vegetable farms has received wastewater for over 20 years, due to the agriculture practices. Over the years, the farmers have been collecting wastewater from the irrigation canal (gravity flows) to a large well and lifting the water by pumps to irrigate the farms farther afield. Thus, the wetland receives water that is lifted and also the run-off from the adjacent fields (Figure 15.5). It is envisaged that in a functional wetland the outlet water can be stored in a well (TWW) for irrigation purposes.

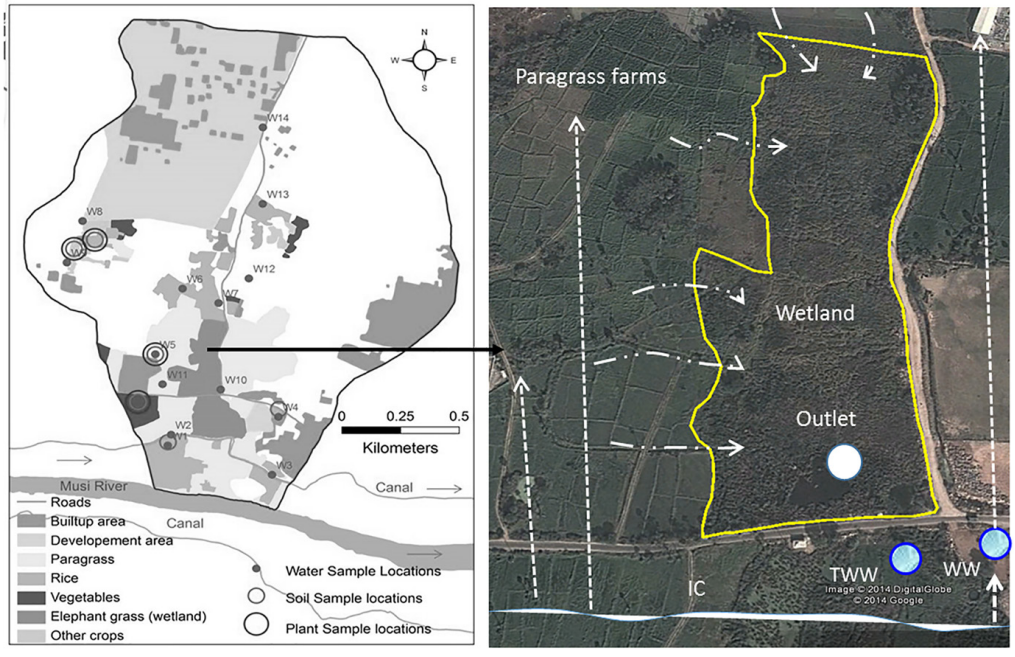

Figure 15.5 Map of the study area (see Chapter 11) and proposed community-managed wetland in Kachiwani Singaram, Hyderabad. IC = Irrigation channel; TWW = Proposed treated wastewater storage well; WW = Wastewater refill well (from irrigation channel). White straight arrows = wastewater lifted for irrigation; curved white arrows = waterflow direction towards the wetland (Google Maps, 2014).

The chemical analysis of water at the inlet and outlet points of the wetland showed that reduction in nitrates and sulphates were significant, during both pre- and post-monsoon seasons (Figure 15.6). Phophate reduction was not consistent through the seasons. It is well known that the removal of nitrates is by plant uptake, and usually occurs in the submerged vegetative parts of the plant and close to the soil, where the oxygen is less. Phosphates usually gets bound to the soil and is removed from water, contributing to the reductions. More detailed investigations are needed to fully understand the dynamics of pollutant removal, however, these results indicate that the hydraulic residence time and the discharge rates are conducive for contaminant removal, for a column of water that passes through this wetland. As such, there is potential for the wetland to be engineered to treat the wastewater for irrigation use.

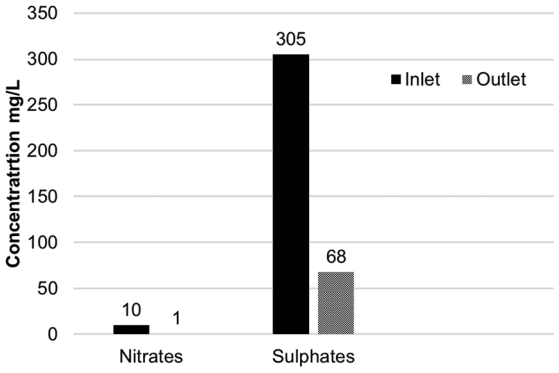

Figure 15.6 The nitrate and sulphate concentrations during the pre-monsoon season (2013) at the inlet and outlet points for the natural wetland.

15.5.2 Percolation pond and check dam in Chennai

Percolation pond

Percolation ponds are effective recharge structures that also offer contaminant removal as the water is passaged through the soils. Ultimately, they help to recharge the aquifer and reduce salinity. A constructed farm pond ($8 \times 8 \times 1.75$ m) with a capacity of 112 m^3 was able to dilute highly salinized groundwater and also augment the groundwater levels in the surrounding areas (Deliverable D 2.3, Saph Pani). This was constructed in Andarmadam, Thiruvallur district of Tamil Nadu, to collect the run-off water from the surrounding areas during the rainy season. These ponds can be constructed in farms with clear management instructions so that groundwater storage can be augmented through aquifer recharge. This type of recharge strucuture can be positioned where the drinking water supply sources are, especially close to townships and can be placed under the CMW integrated urban water management plan.

Check Dam

Check dams across drains, ditches and rivers enhance infiltration and help to recharge aquifers. It also affords the removal of contaminants, during the infiltration process and can help augment the water supply for the city of Chennai through aquifer recharge. A check dam located at a distance of 50 km northwest of Chennai across Arani River at Paleswaram was investigated for its treatment capacity. The study revealed that about 50% of the water harvested is recharged every year. Approximately 1.1 million m^3 of water is recharged if the annual rainfall is about 1,200 mm. A total of 19 check dams have been constructed in the Arani as well as Korattalaiyar River, which are expected to improve the groundwater storage in the area.

15.6 AN INTEGRATED MANAGEMENT PLAN FOR NATURAL TREATMENT SYSTEMS

The major natural processes that take place in the NTS are sedimentation, bacterial degradation, chemical adsorption and plant uptake. An understading of these processes that take place in any given setting is important for its successful adoption. The treated water can be used for an array of different purposes within a city, based on the level of treatment. Careful monitoring is thus required if it is to be used for potable or non-potable use. The integration of an NTS into the current water supply and sanitation plans is a new idea for these two cities. While both cities are facing water scarcity issues, novel ideas such as these have to be discussed among stakeholders that have a stake in it. The reasons for this are, firstly, that NTS have not been considered as part of an urban water

management cycle, therefore, their acceptability for any proposed use has to be endorsed by the relevant authorities; secondly, their management framework has to be developed and integrated into the exisiting water supply systems for sustainability. Finally, the personnel and capacity building of its staff have to be identified and training methods have to be developed.

The two NTS described here are to be used for two different purposes. The one in Hyderabad is for agriculture use and the one in Chennai is for MAR to augment the groundwater supply. The studies showed that periodic monitoring of NTS performance is a must, as it is important to see if contaminant removal takes place continuously, in a satisfactory manner. Thus, the water quality monitoring should be carried out systematically, to see that water is cleaned to a desired standard for its reuse. While both systems described here are compared in their natural states, further fine tuning and adaptation to the local settings is recommended. Each system should have its own management plan, linked to the overall water management plan, which can be monitored by the relevant municipality. Since, NTS have not been considered as a treatment method in both cities, it was viewed as important to discuss the relative merits of NTS to raise awareness among different stakeholders and to obtain concurrence. Here we discuss the acceptance of the NTS as treatment systems by local stakeholders and how they could fit into an integrated water management plan of a city.

15.6.1 Stakeholder concurrence – Hyderabad

The stakeholder perceptions and concurrence were sought during a one day workshop titled "Wetlands as Natural Treatment Systems for Wastewater Treatement and Reuse". The stakeholders as well as the project partners were of the view that NTS could be a viable option for cities where drinking water supply becomes an issue during the summer months. The government stakeholders from 13 departments discussed aspects relevant to implementation, cost benefits and health concerns (WHO, 2006) as the proposed plan was for a community-managed system that was producing food for human consumption. The Hyderabad NTS was perceived as a viable option for farmers using marginal quality water without treatment in the peri-urban areas, which was a major concern especially in the production of green leafy vegetables. It was also felt that further elaboration on how farmers can establish such systems in the field, field testing with multiple field crops and appropriate water/food quality tests as per the recommendations of the WHO guidelines should be carried out. Thus, its potential to be used across agricultural and horticulture crops as well as non-edible crops, were well received. The proposal for two other possible wetland scenarios were also accepted, and these were, i) constructed wetlands and ii) mini wetlands for individual farmers. A few of the important considerations were that gravity flow was adequate to run the systems (no energy use) and required low maintenance, however, quality control has to be a key component of the integrated management plan. A separate stakeholder study revealed that constructed wetlands could be a viable option if the costs of establishment could be supported by the government, and will have important policy implications (Starkl *et al.*, 2015).

Table 15.3 List of agencies that participated in the stakeholder meeting held in Hyderabad.

	Department/Institute
1	Groundwater Department, Government of Telangana, India
2	Central Ground Water Board, Ministry of Water Resources, Government of India
3	National Remote Sensing Centre, ISRO, Hyderabad, India
4	Hyderabad Metropolitan Development Authority, India
5	Central Research Institute for Dryland Agriculture, Hyderabad, India
6	Commissioner, Agriculture, Telangana, India
7	Irrigation & Command Area Development, Water and Land Management Training and Research Institute, Telangana, India
8	Irrigation & Command Area Development, Andhra Pradesh, India
9	Special Commissioner, Department of Rural Development, Andhra Pradesh, India
10	Dept. of Geochemistry, Osmania University, India
11	International Water Management Institute, Patancheru, Telangana, India
12	CSIR-National Geophysical Research Institute, Hyderabad, India
13	Centre for Environment Management and Decision Support, Austria

Source: Saph Pani, News Letter 6 (2014).

The following is a synopsis of the outcomes of the workshop:

- The wastewater in irrigation canals should not be applied directly to crops, unless the water quality is tested prior to application, and is found to be suitable – following the WHO guidelines.
- Based on the contaminants the NTS should be further designed for contaminant removal.
- NTS treated wastewater can be used conjunctively with groundwater.
- Since it is a community-based NTS, the government involvement is a must for quality control.
- Finance schemes should be aligned to provide financial support communities as an incentive to use NTS as part of their agriculture practices.

Figure 15.7 depicts a possible integrated urban water management plan for Hyderabad. The city managers accept that urbanisation has influenced the development of large peri-urban spaces which provide many types of services that are needed for city dwellers. As such, there is a constant demand for the utility services to be extended to these spaces and the GHMC has been heeding to some of the requests over the years. However, the administration is beginning to realise that it is a timely proposition to explore some of the alternative sources to meet the potable as well as non-potable demands and also see that both quality and quantity are maintained for these sources through natural processes that are more cost-effective. For example the Musi River, which provided clean water for peri-urban agriculture in the past, has become a highly polluted river, rendering it unsuitable for irrigating food crops. The NTS that were studied offer new opportunities for municipalities to explore new methods of treatment of wastewater for food crops as well as non-potable uses like landscaping and industrial cooling. The municipality can play a key role in the design and management and has access to more water treated to a level that can be used. In this chapter we propose two types of constructed wetlands, one at the point of the irrigation channels and the other on farmer plots where the non-point source pollution contamination can be addressed before it is used for food production. Both types of constructed wetlands can be part of the urban water cycle where the municipality is responsible for the overall management and quality control. The consutruction of the larger wetlands can be introduced as part of the overall sanitation program and the farmers can be incentivised to build and manage the small NTS on farmer plots. In this way, the urban water supply, city sanitation plans and natural treatment systems can be part of an integrated plan, where the quantity and quality of water supply can be addressed at the same time.

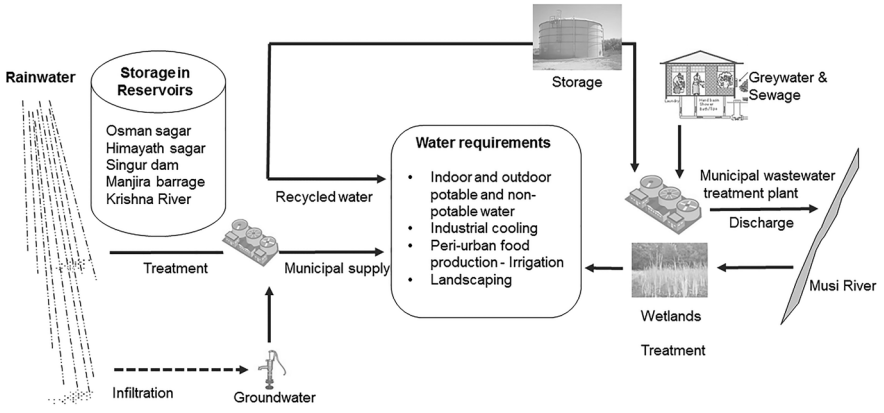

Figure 15.7 A schematic diagram of an integrated water management plan for Hyderabad that includes a natural water treatment system (Wetland).

15.6.2 Stakeholder concurrence – Chennai

The gap between the supply and demand for water for the city of Chennai has been increasing over the years. The current thinking of the water supply agencies is to plan for additional desalination plants to reduce the gap. However, the cost of desalination plants work out to be INR 8,712 million (Deliverable D6.2, Saph Pani). To improve the groundwater storage in the urban part of the city, rainwater harvesting has been in practice since 2003. However, the efficiency of the rainwater harvesting structures is questionable. There is a need for a regulatory authority to monitor the installation and functioning of these recharge structures and to assess the efficiency annually. In the urban and peri- urban as well as rural areas the groundwater recharge needs to be increased by the construction of small percolation ponds, and check dams to harvest the surface run-off, which is currently about 95 million m^3 from the Arani River basin to the sea, north of the city of Chennai. If

10,000 percolation ponds (8 × 8 × 1.75 m), are constructed, in the rural areas, north of the city of Chennai, it will result in the harvest of about 11 million m^3, which is about 12% of the existing run-off to the sea. The suggested recharge initiatives may lead to an increase in groundwater availability by 10 million m^3/year. Hence, the contribution of groundwater to meet the city water requirements can be increased rather than increasing the number of desalination plants.

The percolation ponds and the check dams can be viewed as part of both urban and rural watersheds and integrated into the city water supply system if a good monitoring system is established to test the water quality at these water harvesting structures. In both cases maintaining a good hydraulic flow is important for contaminant removal. A possible schematic framework for management of these strucutures is given in figure 15.8. The design and management of these structures can be part of the mandate of the municipality and/or the watershed development department depending on the positioning of strucutures. Both the watershed department and the municipality can monitor these strucutres together, ensuring that the desirable standards for drinking water is maintained. One important component of such a system is capacity building and must be inlcuded as part of the regular management plans.

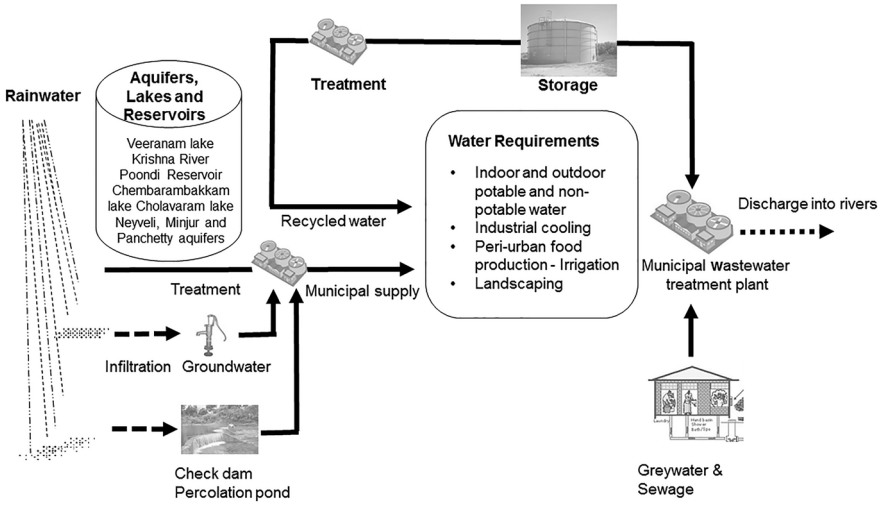

Figure 15.8 A schematic sketch of an integrated urban water management plan for Chennai that includes two natural water treatment systems (Check dam and percolation pond).

15.7 CONCLUSION

This chapter explores the integration of two NTSs into the urban water supply systems, in each of the cities. These systems can be cost-effective means of treating alternative sources of water that is available in and around cities, for food production and to augment the drinking water supplies. In Hyderabad a natural wetland, situated about 15 km downstream of the city, was capable of reducing contaminants in its natural state and displays the potential to be further engineered to achieve the desired water quality levels for reuse in agriculture. If such engineered wetlands can be utilised within urban and peri-urban settings, it can help to treat contaminated free flowing water to be used for alternative purposes like agriculture, landscaping, industrial cooling and other non-potable uses in the city.

The rapid and heavy rains in Chennai result in quick run-off with poor recharge via infiltration. The run-off water could be, to an extent, harvested by different structures developed for MAR. In Chennai, the check dam and pilot percolation pond that were studied for their treatment potentials indicated that both can be successful methods to lower salinity and unwanted contaminants. It was a good example of a successful MAR, which can be used for augmenting freshwater supplies, especially in coastal areas.

Urban water management is facing unprecedented challenges in both cities and the exploration of alternative sources is well timed. With source water contamination and diminishing aquifer sources, India needs to look at some of the natural systems for treatment and integrate it as part of its water resource management plans. Integrated water management plans can bring together all sectors linked with water to look at issues holistically. Involvement of key stakeholders in the discussion enhanced the awareness on NTS, and the importance having alternative solutions to treatment of urban run-off and other contaminated water sources in and around the cities, especially in peri-urban spaces. The government stakeholders were willing to pilot these ideas furthers in another phase. The Figures 15.7 and 15.8 illustrate how NTS can be positioned in a

total urban water management plan, which can then be considered as part of a larger planning and management process. The need for running pilots for up-scaling can be a part of a short and long term goal setting process of the municipalities, where cities can look for alternative measures to augment the water supply to meet different demands. It is clear that testing and validating is a time consuming process. The need for key government institutions to play an active role in identifying the relative roles for effective and sustainable management will herald a change in the current thinking of using only expensive methods of treatment. Once the NTS are included as part of the urban water supply system, its overall management and quality control can ensure sustainability. Integrated water resource management allows coordinated, responsive actions across water users and service providers to plan for innovative sustainable options for augmentation. However, success also depends on securing significant funds for operation and maintenance of systems, proper capacity building of its staff and supportive policies.

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