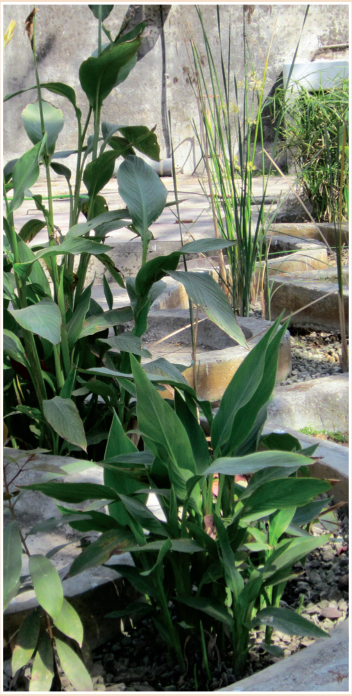
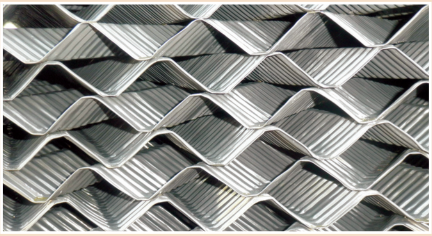
Decentralised
Wastewater Treatment and Reuse




Case studies of implementation on different scale – community, institutional and individual building

Decentralised
Wastewater Treatment and Reuse

Case studies of implementation on different scale – community, institutional and individual building

Centre for Science and Environment

Direction and coordination
Suresh Kumar Rohilla

Research
Mahreen Matto
Deblina Dwivedi
Chhavi Sharda
Aditi Tallu

Design Layout
Surender Singh

Cover design
Vivek Bhardwaj

Production
Rakesh Shrivastava
Gundhar Das

We are grateful to the Comprehensive Capacity Building Programme under Jawaharlal Nehru National Urban Renewal Mission (CCBP- JnNURM), Ministry of Urban Development for the support.

Published by:
Centre for Science and Environment
41, Tughlakabad Institutional Area
New Delhi – 110 062, India
Ph: 91-11-2995 6110, 2995 5124, 2995 6394
Fax: 91-11-2995 5879, 2995 0870
Email: cse@cseindia.org
Website: www.cseindia.org

CONTENTS

ACKNOWLEDGEMENT

We would like to thank all the implementers, developers, beneficiaries – individuals and organisations those who shared their knowledge, ideas and case studies with CSE water researchers, gave their time to patiently answer all queries and provided data, illustration and photographs.

We have reviewed over 19 case studies from across country, but not all of them are included in the report due to paucity of space. The remaining selected case studies from across India will be put up on our website.

Executive Summary

Wastewater management in urban India has focused on creating centralised systems of sewerage networks to provide treatment and disposal. The conventional technologies of wastewater (sewage) collection and treatment are natural resource intensive (use water first to flush, then to carry the waste), but also capital and energy intensive. As per some recent estimates, 50-80 per cent of untreated sewage is disposed in the water bodies. The fact is that Indian cities have the opportunity to reinvent sewage paradigms, simply because they have not yet built infrastructure. They can leapfrog into new ways of dealing with wastewater, which are affordable and sustainable.

Need is for looking at the appropriate wastewater treatment alternatives and applying more integrated approach for diverse ecosystems. The alternate approach of decentralised wastewater treatment (DWWT) is based on the important principle – devolving level of application so that sewage can be treated at affordable costs, cutting the cost of pumping long distances and promoting local reuse of treated sewage. Wastewater treatment and local reuse – at community, institutional and individual building level applying locally adequate treatment technology can help achieve the twin objectives of equity and sustainability.

Jawaharlal Nehru National Urban Renewal Mission (JnNURM) included reform initiatives highlighting the need for sustainable infrastructure development in Indian towns/cities. The mid-term review highlighted on building more centralised systems, creation of more infrastructures, laying more pipelines and installing sewage treatment plants (STPs). The capital cost for conventional STPs was mostly met out of grant funding, but the operation and maintainance (O&M) expenses need to be generated by the urban local body at most times. But the revenues generated by local taxes including water and sewerage charges in coverage area are too meager to even break in the local body accounts, leave alone increasing the reserve funds. The review recommends the urgency for affordable and sustainable wastewater system linking with the socio-economic and environmental impacts. Need is to have more information on issues, challenges and potential of alternative approaches like DWWT and local reuse at different scale – community, institutional or individual building.

This report has reviewed 11 case studies out of total 19 projects of DWWT identified from across India. The initial selection has examined both natural and electro-mechanical/ chemical decentralised wastewater treatment technologies. After detailed analysis three case studies of implementation on different scale have been selected – one each at community, institutional and individual household building. All three case studies use natural technologies with minimal or no electricity requirement for treating wastewater and also locally reuse treated water.

First, is the case study of Naval Civilian Housing Colony located in Kanjurmarg, Mumbai known for neighbourhood/community scale wastewater treatment using – *Soil Biotechnology* (SBT). The DWWT system implemented is treating 50 KLD wastewater generated from 168 households residing in seven residential blocks. The treated wastewater is used for meeting the horticultural water requirements. Second, case study is of the National Environmental Engineering Research Institute (NEERI), Worli, Mumbai treating wastewater using – *Phytorid Technology*. The system treats 5 KLD grey water generated from the bathrooms, kitchens and laboratories. The treated wastewater is locally used for meeting horticultural water requirements. Third, case study is of individual household building DWWT system located in Sangli City, Maharashtra. The wastewater is treated using – *Fixed Film Biofilter Technology* (FFBT). The system treats 1 KLD wastewater. The treated wastewater is used for meeting the horticultural water requirements.

It is evident that all three projects worked on the principle of DWWT using locally appropriate technology required for the type of reuse. All three case studies illustrate applicability of DWWT system planned, implemented and judged in respective settings. The case studies scientifically establish the necessity and potential of DWWT and direct benefits to the users.

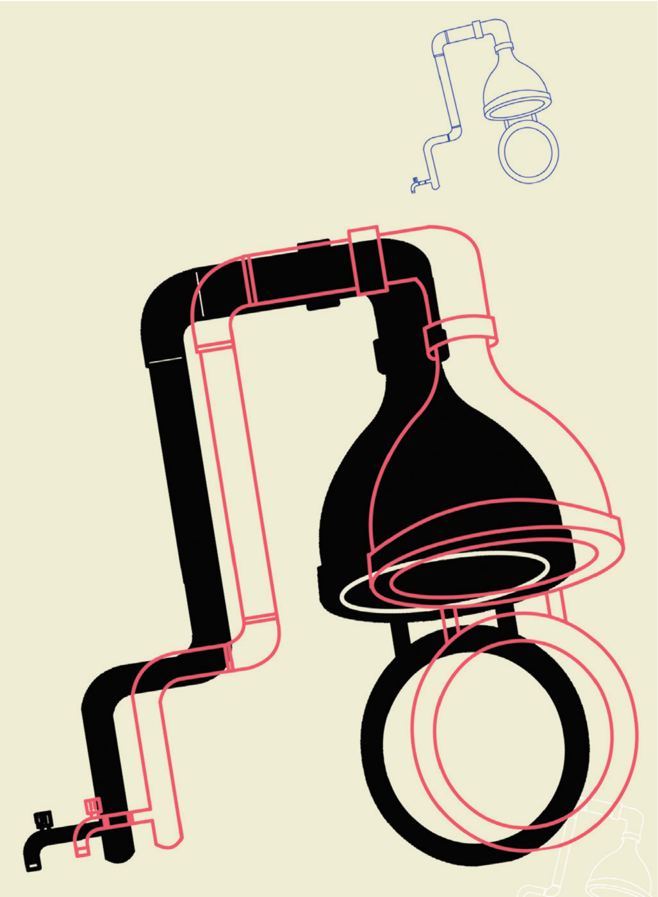
The case studies seek to encourage discussion within urban local bodies (ULBs) and water management organisations about - what they are doing at present and raising questions - what they want to do in the future – what could be done with their wastewater as valuable resource. The aim is to connect and learn directly from implementers as well as beneficiaries and share experiences with all who like to not only learn to upscale, but also mainstream this new technology revolution.

There is clearly an opportunity for ULBs and utilities to reinvent and build resource oriented decentralised wastewater management infrastructure that accommodates the needs of users while fulfilling the public health and environmental requirements.

Introduction

India has witnessed a rapid increase in the urban population during last few decades. All towns and cities are augmenting water supplies to meet the increasing water demand. But the lack of adequate wastewater treatment facilities is resulting untreated sewage disposal into lakes, river and other water bodies. The cumulative result of unmanaged wastewater that the system cannot cope with has negative effects on the health of both people and ecosystems and is a challenge for ULBs.

The revenues generated by local taxes including water and sewerage charges in coverage area are too meager to even break in the local body accounts, leave alone increasing the reserve funds. In this situation, pollution control is a near impossible task. The fact is that Indian cities have the opportunity to reinvent sewage paradigms and they can leapfrog into new ways of dealing with wastewater. DWWT will certainly conserve various resources and, at the same time provide sanitation in unsewered area typically seen in Indian towns and cities.



The socio-economic situation and the context of urbanisation highlight the need for DWWT. In such circumstances, local reuse and recycle of treated wastewater too holds immense potential in terms of overall urban environmental sustainability.

Mainstreaming DWWT and Local Reuse for Sustainable Urban Water Management

Rapid urbanisation in India followed by increasing prosperity has led to steep increase in wastewater generation in towns/cities. But the wastewater collection and treatment are lagging far behind. According to Central Pollution Control Board (CPCB) during 2009 about 38,255 MLD of sewage was generated from class I and II cities out of which treatment facility existed only for 30 per cent i.e. 11,788 MLD *(see Table 1: Status of sewage generation and treatment capacity in urban cities and towns of India).* Now sewage, once generated, has to go somewhere. It invariably does go into streams, ponds, lakes and rivers of a town or city, so polluting the water system, a hazard to the health of the person to whom that water will be supplied. Or, it goes into the ground, contaminating the aquifer. Again water used by people for drinking is contaminated.[1]

The centralised sewage management is and has been the conventional management strategy for the past many decades, extending in urban areas. The business of sewage, building drains and STPs was always the domain of ULBs, aided by some money given in the name of river cleaning. According to CPCB, most of the treatment plants are not operating satisfactorily due to inefficient collection system, lack of finances to run the plant, shortage or absence of electricity and even lack of sewage. For sewage to be treated, it has to be conveyed to the STPs. But most cities do not have sewerage system to intercept wastewater or convey it to the plants.[1]

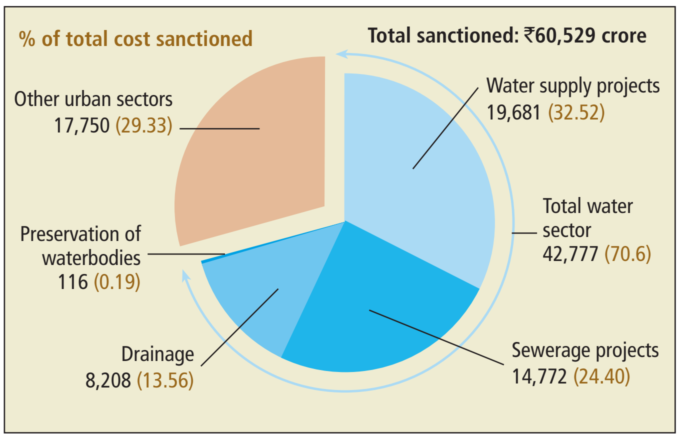
JnNURM phase I started in 2006 by the Union Ministry of Urban Development mainly focused on investing towards building more centralised systems, creating more infrastructure, laying more pipelines and installing electro-mechanical and chemical sewage treatment plants. The conventional collection system, require large amount of capital just for transporting sewage from one place to another (*see Graph 1: Making sewage worthwhile: Sectorwise allocation of JnNURM funds (₹crore) & Graph 2: Blip becomes blast: Money spent on water and sewage over time (₹crore)).*

According to a survey of water – wastewater scenario of 71 cities published in CSE publication 'Excreta Matters' (2012) Indian cities have a two-fold challenge[1] –

- There is huge deficit in connectivity and repair, the connection backlog is immense. Making sewage systems where building and all other construction exist is nightmare
- Cities are expanding, growing in the fringes; here the network doesn't exist. The disconnection only grows. In this situation sewage spills everywhere

Even before sewage can be treated, it has to be

GRAPH 1 Making sewage worthwhile: Sectorwise allocation of JnNURM funds (₹crore)



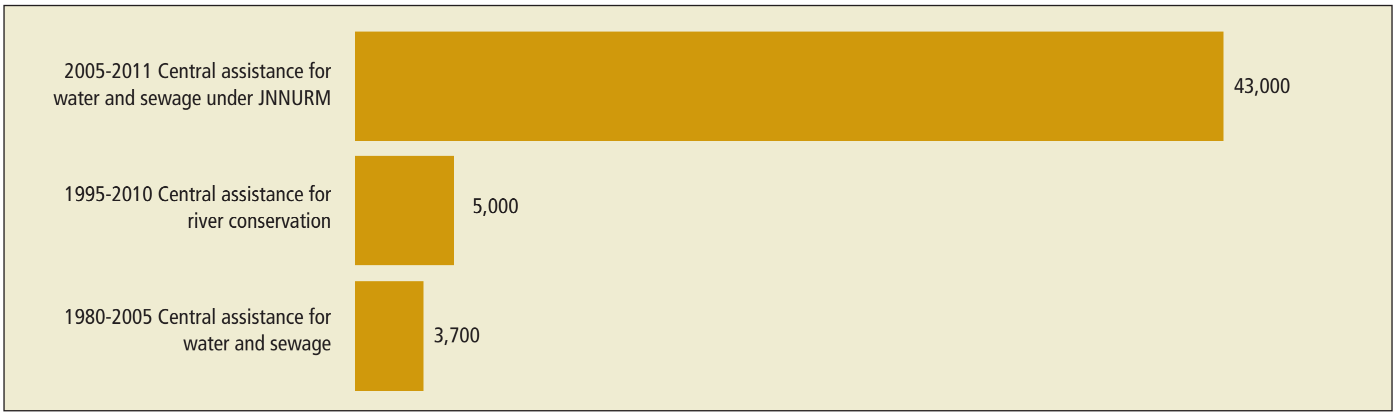
Source: *S Narain 2012, 'Excreta Matters: How urban India is soaking up water, polluting rivers and drowning in its own waste' (CSE)*

TABLE 1 Status of sewage generation and treatment capacity in urban cities and towns of India

Item	Class I cities		Class II cities		Total	
	2006	2009	2006	2009	2006	2009
Wastewater generated (MLD)	26,164	35,558	2,965	2,697	29,129	38,255
Treatment capacity (MLD)	6,047	11,554	2,00	234	6,247	11,788
Wastewater untreated (MLD)	20,117	24,004	2765	2,463	22,882	26,467
Untreated (per cent)	77	68	93	92	79	70

Source: *S Narain 2012, 'Excreta Matters: How urban India is soaking up water, polluting rivers and drowning in its own waste' (CSE)*

GRAPH 2 Blip becomes blast: Money spent on water and sewage over time (₹crore)



Source: *S Narain 2012, 'Excreta Matters: How urban India is soaking up water, polluting rivers and drowning in its own waste' (CSE)*

transported. Cities need drain which officially connect each household through an extensive and intrinsic network of connected pipes to convey the discharge to STPs. According to one approximation, the building of conveyance of one kilometre of sewage network would range between ₹10-40 million and treating 1 MLD of sewage costs another ₹10 million through a centralised treatment system, excluding the land cost.[2] Thus one can assume the finances involved in implementing and sustaining centralised systems to treat the huge quantum of sewage.

In JnNURM, to be eligible for funding, a city must undertake 'reform'. Such reform can be 'mandatory' or 'optional'. As 'mandatory' reform, the ULB or reforming entity has to toe usual market price dictum; states must agree to levy reasonable user charges, such that full cost of O&M or recurring cost is collected within the next seven years. In other words, a full cost pricing regime is mandatory. As 'optional' reform, the ULBs can revise municipal bye-laws to adopt water conservation measure and rainwater harvesting mandatory including introducing bye-laws for reuse of recycled water. But only city of Chandigarh and few other cities have made wastewater recycling mandatory. Very little thought is given to the reuse of treated wastewater from the STPs and mostly it gets mixed with untreated sewage, from colonies not connected to sewerage network.

The conventional wastewater treatment in comparison to decentralised treatment requires a huge running cost in operation and maintenance over and above the capital assets, energy cost and land availability (*see: Appendix 1 and 2: Costs breakup of conventional wastewater treatment technologies & Costs breakup of new emerging decentralised wastewater treatment technologies*).[3] The advantages of decentralised wastewater management system in comparison to centralised are summarised (*see Box: Advantages of decentralised wastewater treatment systems*).

In a decentralised system the wastewater collection networks are shorter in length and smaller in diameter, quantity of wastewater to be treated at the end of network is relatively small and can be managed with variety of simpler and natural treatment methods.[3] In other words, the sewage can be managed at the source of its generation itself (*see Diagram 1: Schematic representation of centralised, combined and decentralised wastewater management system*).

The main difference lies in technology adopted for DWWT system using new emerging natural technologies which can be designed and managed at fraction of the cost of conventional centralised system. The treated wastewater can achieve the standards prescribed by CPCB and can be recycled and reused.[3]

The reuse can also be for non-potable purposes such as toilet flushing, car washing, horticulture/gardening and groundwater recharge and such other uses. The possibilities of local reuse and recycle of treated wastewater are summarised (*see Box: DWWT - Potential of local reuse and recycle*).

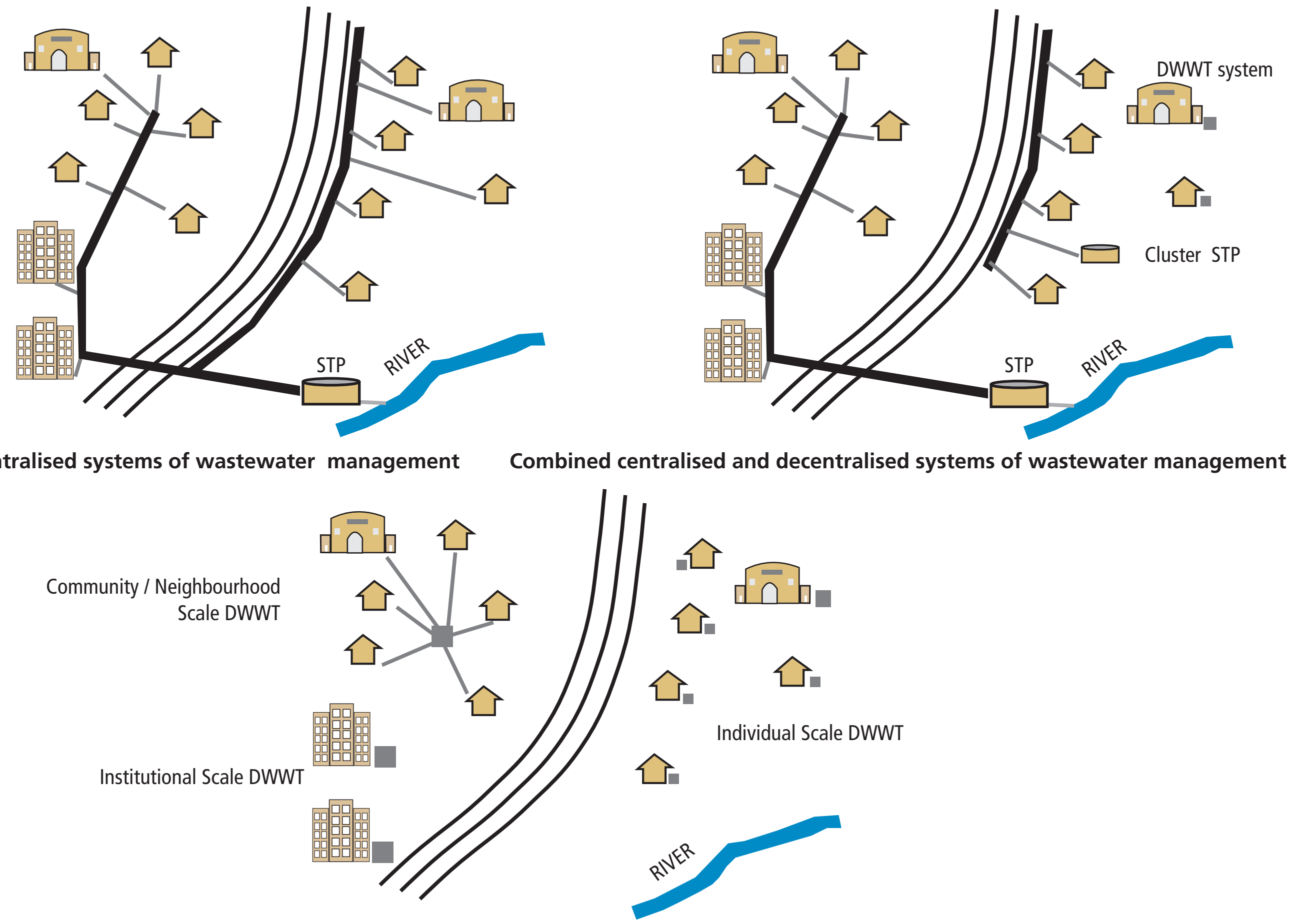
DWWT systems are site specific, innovative and can be designed on the basis of techno-socio-economic feasibility for an integrated solution.

With growing realisation to have sustainable and

Advantages of decentralised wastewater treatment systems

- Site specific and has the flexibility to be designed according to the characteristics of wastewater
- Tolerant to inflow fluctuation (1-1000 m^3/ day)
- Sewer networks are shorter in length and smaller in diameter since there are several disposal points
- Quantity of wastewater to be treated at the end of each network is relatively small
- Possible to use variety of simpler and natural unmechanised treatment methods
- Treats domestic wastewater and wastewater from few industrial sources (food production and processing industries)
- Cost effective sanitation due to low cost operation and maintenance - natural treatment method preferred that require no energy
- Promotes conservation of used water and nutrients as much as possible
- Disposal points are near source of waste generation and available for local reuse
- Promotes a kind of 'public-private partnership' – ULBs / local authorities have to provide lesser capital outlay including low O&M that is taken care by public

DIAGRAM 1 Schematic representation of centralised, combined and decentralised wastewater management system



Centralised systems of wastewater management **Combined centralised and decentralised systems of wastewater management**

Decentralised systems of wastewater management

Source: *CSE TEAM*

DWWT – Potential of local reuse and recycle

Individual household, cluster of building (neighbourhood) or an institutional building, all offer immense potential of local reuse and recycle:

- Non-potable urban uses – toilet flushing, car washing, fire protection, and make-up water for centrally air-conditioned buildings
- Reuse in landscape and agriculture-commercial nurseries, parks/ gardens, roadside/ roadway median strips, golf courses, green belts and irrigation
- Recreational/ environmental uses – development of fisheries, ponds, lakes replenishment, marshes and wetlands
- Aquifer recharge – for replenishment and sustainable groundwater use
- Other industrial non–potable uses like cooling, boiler feed and process water

affordable wastewater treatment various reforms and policies in recent year have made provisions for mainstreaming DWWT and local reuse. The revised manual on 'Sewerage and sewage treatment system' published by Central Public Health and Environmental Engineering Organisation (CPHEEO) in 2013 – has a new chapter dedicated on 'Decentralised sewerage system' (chapter 8, Part A; Engineering) describing the concept as 'localised collection and localised treatment of excreta and sullage in micro zones within a major habitation keeping it in tandem with densification and progressively duplicating it as and when other micro zones densify'.[4]

According to CPCB the decentralised treated wastewater can achieve the standards prescribed and can be recycled and reused.[5]

In all this, growing towns and cities are struggling to find the right answers to treat and clean waste, all at a time, when costs are rising. The ULBs should find scope in decentralisation and exploit a new opportunity in providing sanitation keeping in mind the principle of 'affordability, acceptability and manageability of the treatment' and type of reuse.

Methodology

Research frame

The objective of the study is to document case studies and best practices from across India on DWWT using natural unmechanised treatment methods with minimal or no electricity usage. The documentation include case studies of DWWT implemented at institutional, community and individual household scale providing detailed understanding of the potential for local reuse.

The report is underpinned by an interpretive understanding of knowledge, focussing on meaning that is situated in particular context and acknowledges the subjective nature of real world problems related to sustainable water management in rapidly urbanising towns/cities in India. The research documents how DWWT provisions are understood by relevant actors, and how these different understandings and values are interfacing with policy and practice to produce narratives with help of three different case studies that are implemented at different scale. The aim is to clarify and deliberate about the problems and risks in respective settings and outline how wastewater treatment can be done differently. The case studies discussed offer concrete context dependent knowledge and an attempt to capture complexities and contradictions that happen 'on the ground' at different scale.

The case studies illustrate not just what happened but also why and how it happened and why specific type of intervention (type of technology and local reuse) and for why not alternative intervention and for what reasons. The case studies illustrate good practice examples and a step towards sustainable urban water management in respective settings and do not illustrate typical examples that can be generalised. The 'case studies' were selected from a long list of potential cases.

Case study approach

Case study approach as a research methodology has been used in the given research. A case study can be defined as an 'in-depth' descriptive, exploratory or explanatory analysis of a person, group or event. It is a story about something unique, special or interesting. A case study gives the story behind the result by capturing what happened to bring attention to a particular challenge or difficulty or success in a project. A case may be selected because it is highly effective, not effective, representative, typical or of special interest.[6,7]

A multi-layered criteria for selection was identified. The list has been tested against a set of criteria defined by the research team and the case studies were purposefully selected.

Data collection and analysis

First, desk review identified over 30 case studies from across India with 19 systems using decentralised natural wastewater treatment methods. Second, 11 case studies were further shortlisted on the basis of a combination of criteria such as performance assessment (more than three year steady performance in terms of meeting the water quality norms set by CPCB), socio-economic sustainability (minimal or no electricity use) and reuse of wastewater. Third, three case studies with maximum and high impact have been finalised for documentation against set of criteria – institutional, neighbourhood and individual household building scale project.

The collection of data on DWWT systems across India was done through a variety of approaches. The initial data collection involved desk and archival research followed by telephonic interviews, site visits, in-person interviews and secondary data collection for the shortlisted sites. The goal of the given study is to generate depth of understanding. This entails going after the specific context or a particular piece of information. Therefore, the participants (interviewees) and documents were purposefully selected to help understand the issue/event and meet the overall aim of research.[8,9]

The archival and desk research was followed by site visits to shortlisted sites and in-person interviews with concerned stakeholders. These two activities enabled selection of DWWT using natural methods and detailed gathering of in-depth information at the site which included details on design specifications, O&M, performance monitoring, socio-economic evaluation and environmental benefits. The data collected was both quantitative and qualitative.

The selection of interviewees was done using two types of sampling techniques – judgment/purposive sampling and snowball sampling.[10] The initial identification of the potential interviewees was done based on archival and desk research carried out. This was followed by snowball sampling, where during interview process, all the interviewees were asked who they thought should be approached to get information regarding the DWWT case study, and those persons in turn recommended others. This snowball effect further helped to identify potential interviewees through referrals.[10] Even specific referrals were asked for who could shed light and was knowledgeable about certain aspects of the case and would provide specific information related to the study such as socio-economic impacts, technical information, etc.

The analysis of data collected and information from interviews have been used to explain, what was going on in case study in general sense and supported by interviews. The analysis was validated by comparing it to information obtained from interviews and through extensive discussions within the research team. In addition, the analysis and results were validated through follow up discussions with interviewees and other individuals or organisations representing interest in mainstreaming decentralised wastewater treatment and local reuse for sustainable urban water management. The case studies identified and shortlisted are presented below *(see Table 2: Summary of the DWWT case studies).* The finally selected three case studies have been discussed in the following section.

TABLE 2 **Summary of DWWT case studies**

Type	Selection of case studies		
	Initial	**Draft**	**Final**
Community/ Neighbourhood	• Naval civilian housing colony, Kanjurmarg, Mumbai, Maharashtra – SBT • Lovegrove Pumping Station, Mumbai, Maharashtra – SBT • DTDC Shrinivaspuri, New Delhi – SBT • Kachhpura Village, Agra – DEWATS • Auroville, Puducherry – DEWATS • Banker's Colony, Bhuj, Gujarat – DEWATS • Haus Khaz Lake, Delhi – Bioremediation	• Naval Civilian Housing Colony, Kanjurmarg, Mumbai, Maharashtra – SBT • Lovegrove Pumping Station, Mumbai, Maharashtra – SBT • Kachhpura Village, Agra – DEWATS • Auroville, Puducherry – DEWATS	**Naval Civilian Housing Colony, Kanjurmarg, Mumbai**
Institutional	• IARI, Pusa, New Delhi – Constructed wetland • NEERI, Worli, Mumbai – Phytorid • Mumbai University, Kalina, Mumbai – Phytorid • Sri Ram School, Vasant Kunj, New Delhi – DWWT • Amousi Airport, Lucknow, UP – SBT • Aravind Eye Hospital, Puducherry – DEWATS • Hospital and Residential Building, Sangli City, Maharashtra – FFBT • National College, Bandra, Mumbai – Phytorid	• IARI, Pusa, New Delhi – Constructed wetland • NEERI, Worli, Mumbai – Phytorid • Mumbai University, Kalina, Mumbai – Phytorid • Sri Ram School, Vasant Kunj, New Delhi – DWWTs • Amousi Airport, Lucknow, UP – SBT	**NEERI, Worli, Mumbai**
Individual household	• Residential Building, Krishna Dham, Aligarh, UP – Eco sanitation • Nanda Farmhouse, Chhattarpur, New Delhi – Constructed wetland and pond system • Individual Residential Building, Sangli City, Maharashtra – FFBT • Residential Building, Jath, Maharashtra – FFBT	• Nanda farmhouse, Chhattarpur, New Delhi – Constructed wetland and pond system • Individual residential building, Sangli City, Maharashtra – FFBT	**Individual Residential Building, Sangli City, Maharashtra**

Source: *CSE TEAM,* 2014

Case study: Neighbourhood/Community scale

Naval civilian housing colony, Kanjurmarg (Mumbai)

Objective

The residential housing colony treats domestic wastewater (both black and grey) using 'SBT – natural wastewater treatment methods' and the treated wastewater is used for meeting the landscaping water requirements to maintain green areas – a good example of DWWT and reuse of water at neighbourhood scale, demonstrating the value of water and resource potential by local reuse.

Location and water–wastewater scenario

The residential housing colony is located in Kanjurmarg - a suburb in eastern Mumbai, Maharashtra. The rapid growth in this area can be attributed to its strategic location and proximity to Indian Institute of Technology (IIT), Mumbai. The city of Mumbai has overstretched centralised water-wastewater facilities and is unable to cater to the increasing demand-supply gap. Intermittent supply of water on rotational basis to different wards is common feature in Mumbai. Around 60-70 per cent sewage undergoes preliminary treatment before it is disposed in the sea.[5]

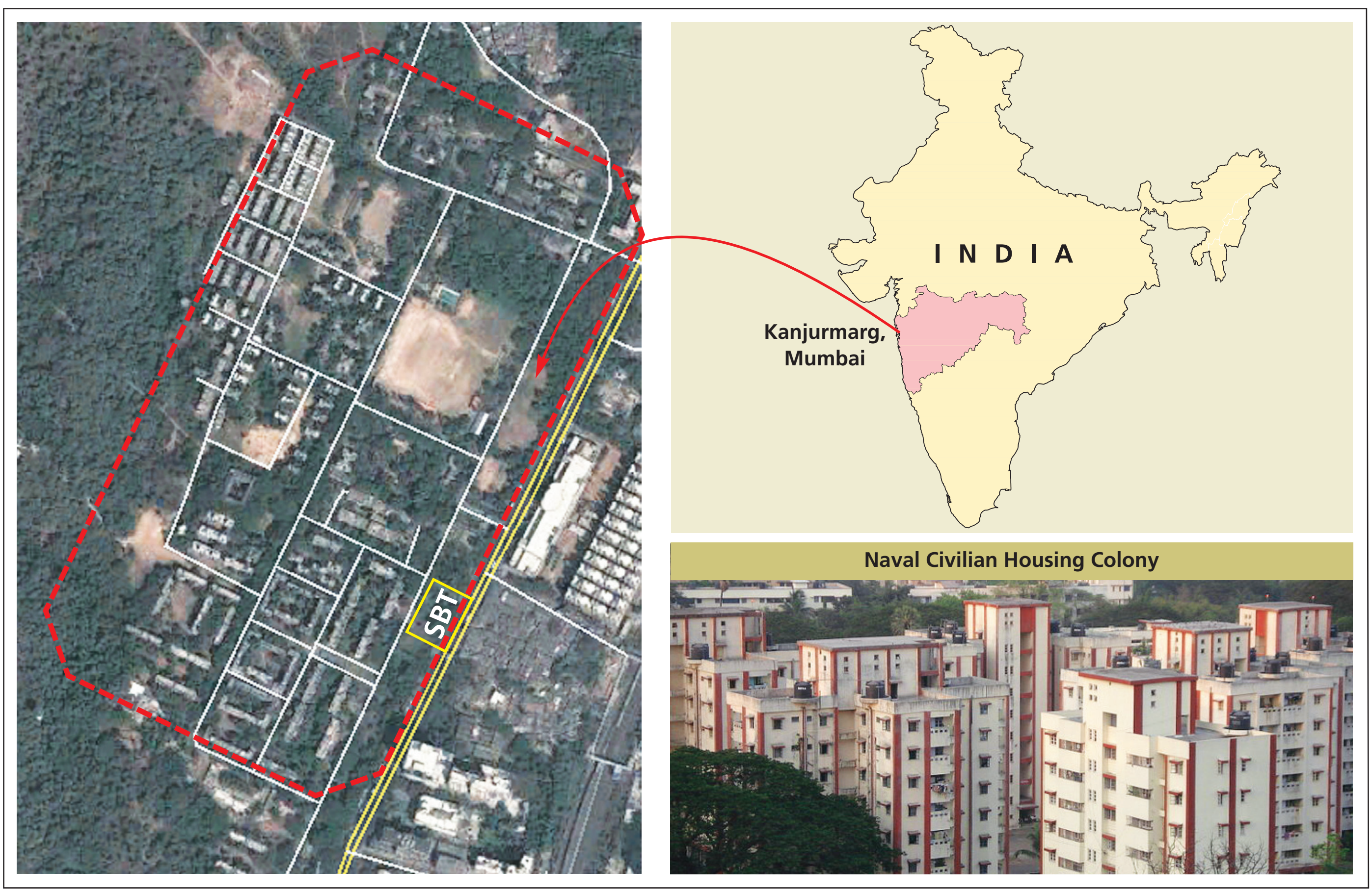
The Naval Civilian Housing Colony is a residential housing neighbourhood for officers and their families (see *Map 1: Location map of the Naval Civilian Housing Colony, Kanjurmarg, Mumbai).*

The area has a lush green landscaping and plantations in the surroundings. Prior to the implementation of DWWT system the water requirement for maintenance of green area and landscaping was dependent on municipal water tankers. The administration was incurring a cost of ₹1.1-1.3 million per annum towards arranging water from tankers.[11]

Decentralised wastewater treatment system

The colony has 20 blocks of buildings with residential facilities, mess, hospital, sports complex, market area and administrative offices. The DWWT system implemented treats the wastewater generated in the neighbourhood from 7 residential building blocks - each building having 24 apartments.[11] The project

Map 1 **Location map of the Naval Civilian Housing Colony, Kanjurmarg, Mumbai**



Source: *Google Map Image*, 2014 *and Wikipedia, 2014*

TABLE 3 Salient features of the DWWT system at Naval Civilian Housing Colony

Parameters	Details of DWWT System
Year of implementation	2002
Technology detail	SBT
Number of Buildings (Flats) wastewater treated	7 Building (24 Flats each)
SBT Plant capacity	50 KLD
SBT Plant area	500 sq.m
Wastewater reused (180 days)	16.2 million litres per annum (45 KLD)
Green area irrigated	2.2 acre
Capital cost of system (in 2002)	₹0.7 million
O&M costs (per annum)	₹0.1 million
Savings (per annum)	₹1.1 million

Source: *CSE Team, 2014*

overview is summarised (*see Table 3: Salient features of the DWWT system at Naval Civilian Housing Colony*).

Keeping in mind the potential of local reuse a DWWT system was designed and implemented by Prof HS Shankar assisted by his students of the Department of Chemical Engineering, IIT, Mumbai. The project is good example of treatment of wastewater generated from neighbourhood buildings demonstrating potential of local reuse in meeting bulk non-potable water requirements i.e. for irrigating the green landscape, parks/gardens and plantations.

Technical specifications, design including O&M

The details of SBT based system - design of treatment process, details of operation and maintenance, system performance (physico-chemical parameters of treated wastewater) and the benefits have been discussed in following sections.

Soil Biotechnology (SBT)

SBT is a green technology for water purification using natural, novel high efficiency oxidation process at competitive costs. The technology is covered by US and Indian patents.[12-15]

The technology combines sedimentation, infiltration and biodegradation processes. It works with formulated geological environment wherein fundamental reactions of nature, namely respiration, photosynthesis and chemical mineral weathering are responsible for bioconversion of sewage. Suitable mineral constitution, culture containing native microflora, geophagus worms and bioindicator plants are the key components of the media.[12-16] Bioconversion takes place by bacterial processing of organics and oxidisable inorganics via natural oxygen supply wherein mineral weathering reaction serves to regulate pH, while green plants serve as bioindicators. The high toxic potential, the neutral pH together with ecology of environment leads to significant reduction in the organic matter, nutrients and pathogens from wastewater.[16]

SBT can be designed to treat any type of wastewater provided the wastewater is not saline (i.e. having total dissolved solids (TDS) < 1000 mg/L typically) and as long as the water is not toxic to micro organisms. SBT process requires temperature; between 20-45 degree Celsius (in low/ very low temperature a greenhouse infrastructure appropriate for the local conditions can house SBT plant. The process can also work at high ambient temperatures.[17]

Salient features of Soil Biotechnology

- Natural processes based wastewater treatment
- No mechanical aeration involved yet enough oxygen produced in the bioreactor
- No sludge generation and smell or odour
- Process can be run both on batch or continuous mode
- Overall time operation (wetting cycle) is 6-7 hours
- Capable of handling shock load of 50 per cent over or under design load for a few days automatically
- Land area requirement range from 1500-2500 sq.m per MLD
- Minimal energy consumption (40-50 KWh per MLD to pump the wastewater for distribution over reactor bed)
- O&M cost of SBT plant costs ₹2-4 per KLD per annum (₹4000 per MLD per annum)
- No skilled labour requirement for O&M

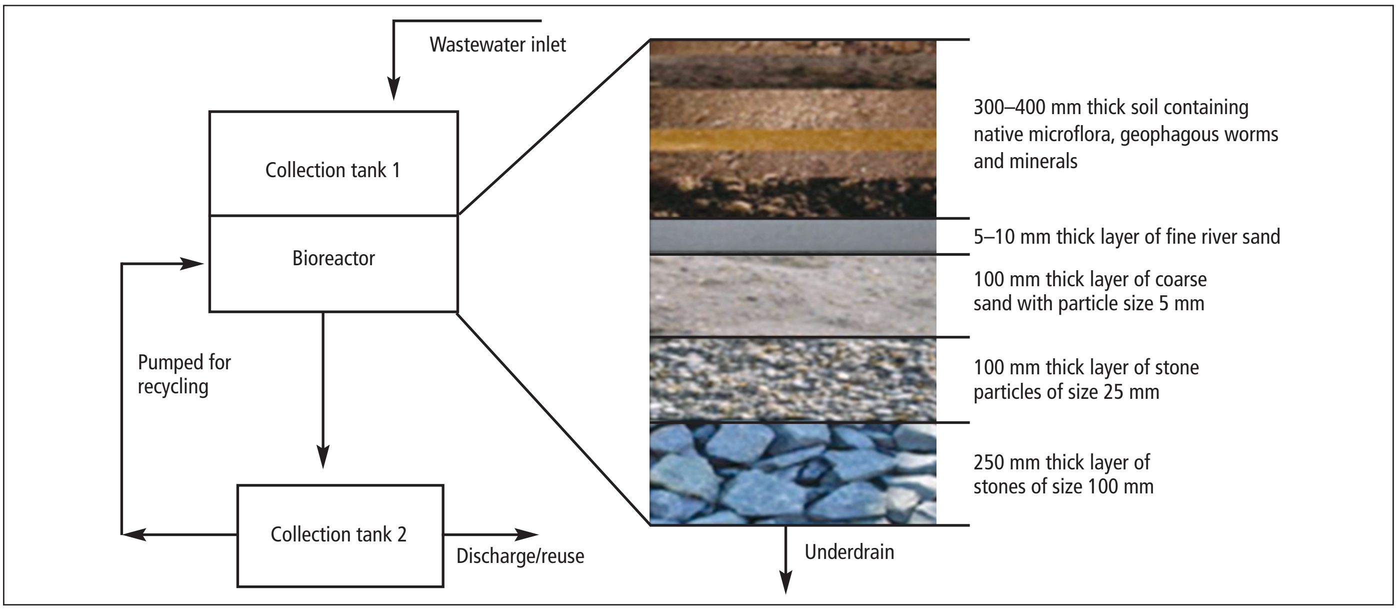
Treatment system, design and construction

The major component of system is bioreactor, which is constructed from reinforced cement concrete (RCC)/ stone-masonary or soil bunds. The bioreactor can be constructed above or under the ground. The SBT system also consists of coarse or fine screen chambers/grit chamber for preliminary treatment, treated water tank, piping, pumps and electrical (*see Diagram 2: Schematics of SBT and the bioreactor showing different layers of filter materials*) and civil works.[18] The SBT treatment plant biofilter is located on 500 sq.m area. The total land area including the collection tank and treated water storage tank of DWWT system is 625 sq.m.

The bar screens of 5 mm and 3 mm aperture size are used to remove the coarse and fine suspended solid particles from wastewater. The bioreactor consists of an underdrain which is covered with layers of different size gravels, coarse and fine sand, culture, media, additives and bioindicators. It consists of microbial culture (native microflora, geophagus earthworms) required for breaking down and bioconversion of the sewage. Green plants particularly with tap root system act as bio-indicators. To avoid leaching of partially treated wastewater into aquifer and to provide a firm foundation for construction soling is done. This is done with stone aggregates of random sizes between 50-150mm. This is followed by fabrication, assembling, fixing and testing of polyvinyl chloride (PVC) network is done on the top of bioreactors and for the under drain.[18]

After screening and grit removal the water percolates through the trenches (containing gravels) and gets collected in the collection tank. Suspended solids are retained on the top layer with gravels. Water is then pumped and circulated to the bioreactor through a piped distribution system. Water trickles through different layers in the bioreactor and undergoes treatment through a combination of bioconversions which takes place due to respiration, mineral weathering, photosynthesis and bacterial action.[17-20]

DIAGRAM 2 **Schematics of SBT and the bioreactor showing different layers of filter materials**



Source: *HS Shankar et al 'Soil conditioning products from organic waste', Patent No: 7604742B2. October 2009. US*

The treated wastewater gets collected in the collection tank and can be recirculated till desired quality is achieved. Suspended solids are either retained on the trenches or top layer of the bioreactor (depending upon the design of the bed). They are removed periodically from the top by scrapping and can be discarded into the municipal solid waste. The treated wastewater can be reused for horticulture purpose.[17-20]

"The SBT plant requires minimal O&M periodically that includes cleaning of pipes, scarping of the top surface to remove the settled suspended particles. The microbial culture is tested and recommended to be changed every 8-10 years. The system does not require highly skilled labour"

— Dr AM Kadam, Sugham Paryavaran Pvt. Ltd.

Treatment system at Naval Civilian Housing Colony

The SBT plant in this colony consists of a raw water collection tank, a constructed soil filter bioreactor and an effluent collection tank. The raw sewage after screening is collected in the tank from where it is directed towards the trench filled with gravels. Each trench is 25 m long and 1.5 m wide. The sewage is then pumped and distributed over the reactor bed. The bed surface area is 500 sq.m. The total depth of the bed is 0.7 m with 0.3 m of red soil layer (laterite soil) and 0.4 m of layer of stone at the bottom.[19]

The treated sewage gets collected in the effluent collection tank and is (re)circulated in order to achieve the desired quality

CSE TEAM

Trickling of wastewater through u-PVC pipes on the bioreactor

TABLE 4 Treatment efficiency of SBT plant at Naval Civilian Housing Colony

Parameters	Inlet (avg)	Outlet (avg)
pH	7.0	7.4
DO (mg/l)	0.72	4.8
TSS (mg/l)	187.8	9.1
BOD (mg/l)	95.3	5.9
COD (mg/l)	187.9	8.3

Biological Oxygen Demand (BOD); Chemical Oxygen Demand (COD); Dissolved Oxygen (DO); Total Suspended Solids (TSS)
Source: *AM Kadam*

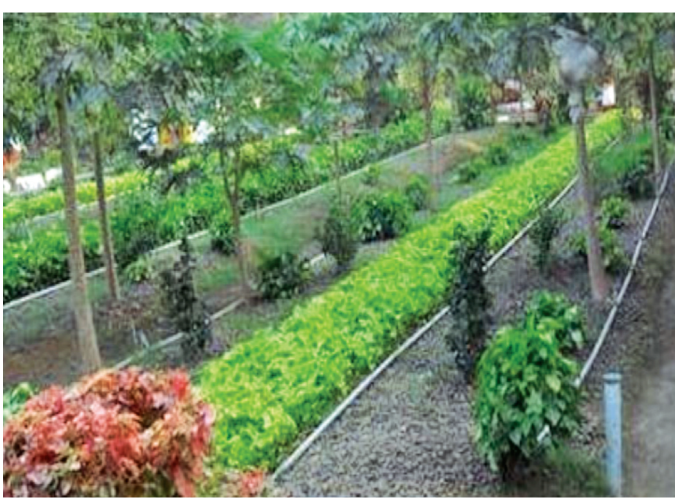
of treated wastewater. Half the volume of water is recirculated with a batch running time of 6.5 hours. The bed is then rested for drying prior to next cycle of use. The green plants used in the system are only for ornamental purpose and add to the aesthetics of the environment (*see Photograph: SBT based bioreactor for wastewater treatment at Naval Civilian Housing Colony*).[11,19]

System performance including O&M

The SBT plant has been functioning for over 12 years. The treatment efficiency and overall performance of the system is being regularly monitored (*see Table 4: Treatment efficiency of SBT plant at Naval Civilian Housing Colony*).

The performance results indicate increase in DO in wastewater from negligible level in the absence of any external energy consumption. Further the reduction of BOD by 90 per cent in the system reveals good performance. The performance at outlet indicates that treated wastewater can be safely reused for horticulture purpose as it meets all the standards prescribed by CPCB.

> **"Easy operation is the main feature of SBT. To ensure smooth functioning of the system, it is checked that there is adequate water in the raw water tank. The system will automatically shut off if the level of water falls below a minimum safety threshold in the raw water tank"**
>
> *— Mr. Timothy, Responsible for O&M, Indian Navy*


A KADAM

SBT based bioreactor for wastewater treatment at Naval Civilian Housing Colony


CSE TEAM

SBT gravel trench and bioreactor

The average O&M costs for 50 MLD plant comes to around ₹100,000 per year including the electricity costs.[11,21]

Socio-economic and environmental benefits

The housing colony has a 1.5 km long linear stretch of green area and well maintained parks/gardens with lush green trees, plants and landscaping. The treated water is locally used for maintaining estimated green area of 2.2 acre. The treated water is used for meeting 180 days horticultural water requirements. The DWWT system includes a collection tank for storing 20 KLD treated water and the remaining excess water is disposed in the municipal sewerage system. The project is a high visibility and high impact intervention with considerable socio-economic benefits in the neighbourhood. It is also a pioneering attempt demonstrating safe and acceptable local reuse of treated wastewater.

The DWWT system has reduced dependence of the neighbourhood on water tankers. Prior to the implementation of SBT plant 6-7 tankers were required to supply water for meeting green area and landscaping water requirements in the neighbourhood. The average cost of water tanker (capacity 8,000 litres) in Mumbai is ₹1200 per tanker.[11] During last 10-12 years the society has met all water requirements of maintaining green area by local reuse of the treated water available from

> **"I am in-charge of cleanliness in the colony since August 2012. The area has limited water availability. But with treated water from the SBT plant the entire horticulture demand is being met. There is no smell or mosquito breeding unlike other wastewater treatment units"**
>
> *— Mr. Hemant Kumar Jha, Sulabh International Worker*

Quality of wastewater – before and after treatment

CSE TEAM

Wastewater before treatment

CSE TEAM

Wastewater before and after treatment

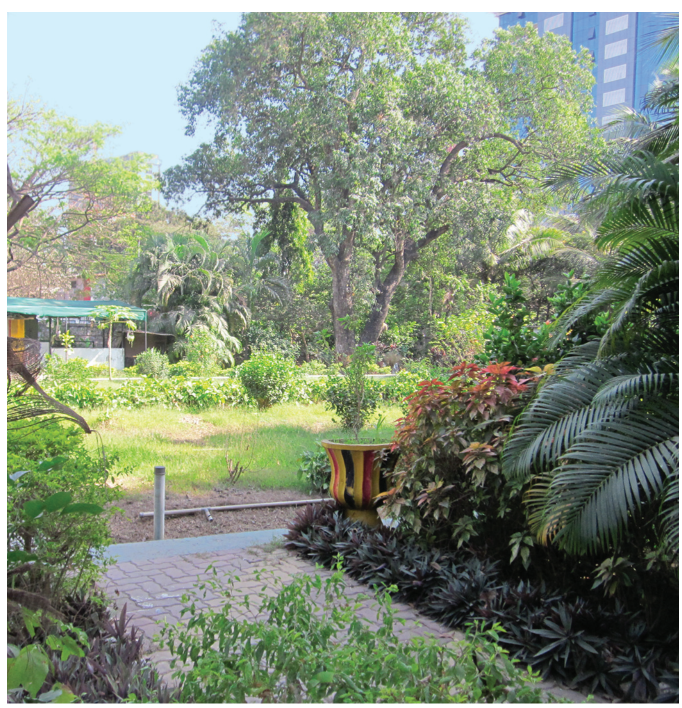
> **"The SBT in the society is rich in biodiversity. The treatment plant enhances the landscape feature of the society. Herbal and medicinal plants like Tulsi and Haldi are growing around the bioreactor and are being used by the society people. I am very happy to have a wastewater treatment plant with green surrounding in my colony"**
>
> *— Mr. Ramesh Baile, Resident of P Block of the Colony*

SBT plant. The reuse of treated water has resulted ₹1.1 million savings annually.

The housing colony caters to family accommodation for senior officers. The Naval administration (estates department) maintain lush green areas and has considerably added to the improvement of micro climate. The parks and garden irrigated by locally treated water are used by residents for recreational activities, thereby leading to area appreciation and highlighting the potential for conserving in-situ resources.

SBT plant itself has added to the aesthetics in the neighbourhood and is an absolute example of how environmental benefits can be achieved. Over 12 years of operation of the system, no health issues, bad odour or mosquito breeding is reported due to existence of DWWT facility in the neighbourhood or due to local reuse of treated water. The implemented project at neighbourhood scale is clear valuable resource cum facility for the residents and demonstrates to other practitioners the environmental benefits and its potential.

CSE TEAM



Green stretches irrigated by treated wastewater

Case study: Institutional scale

National Environmental Engineering Research Institute (NEERI), Worli (Mumbai)

Objective

The key objective of the project was to successfully demonstrate treatment of wastewater (grey water) generated in the institute and local reuse for meeting the horticulture water requirements. The project is a good example of sustainable urban water management in a rapidly growing large city of Mumbai and demonstrating the potential of appropriate local reuse of treated water based on the level of disinfection.

Location and water-wastewater scenario

The institute is located in south Mumbai. Intermittent supply of water on rotational basis to different wards is common feature in Mumbai. Around 60-70 per cent sewage undergoes preliminary treatment before it is disposed in the sea.[5] The rapidly growing city of Mumbai has overstretched centralised water-wastewater facilities and is unable to meet increasing demand-supply gap of the water and wastewater treatment.

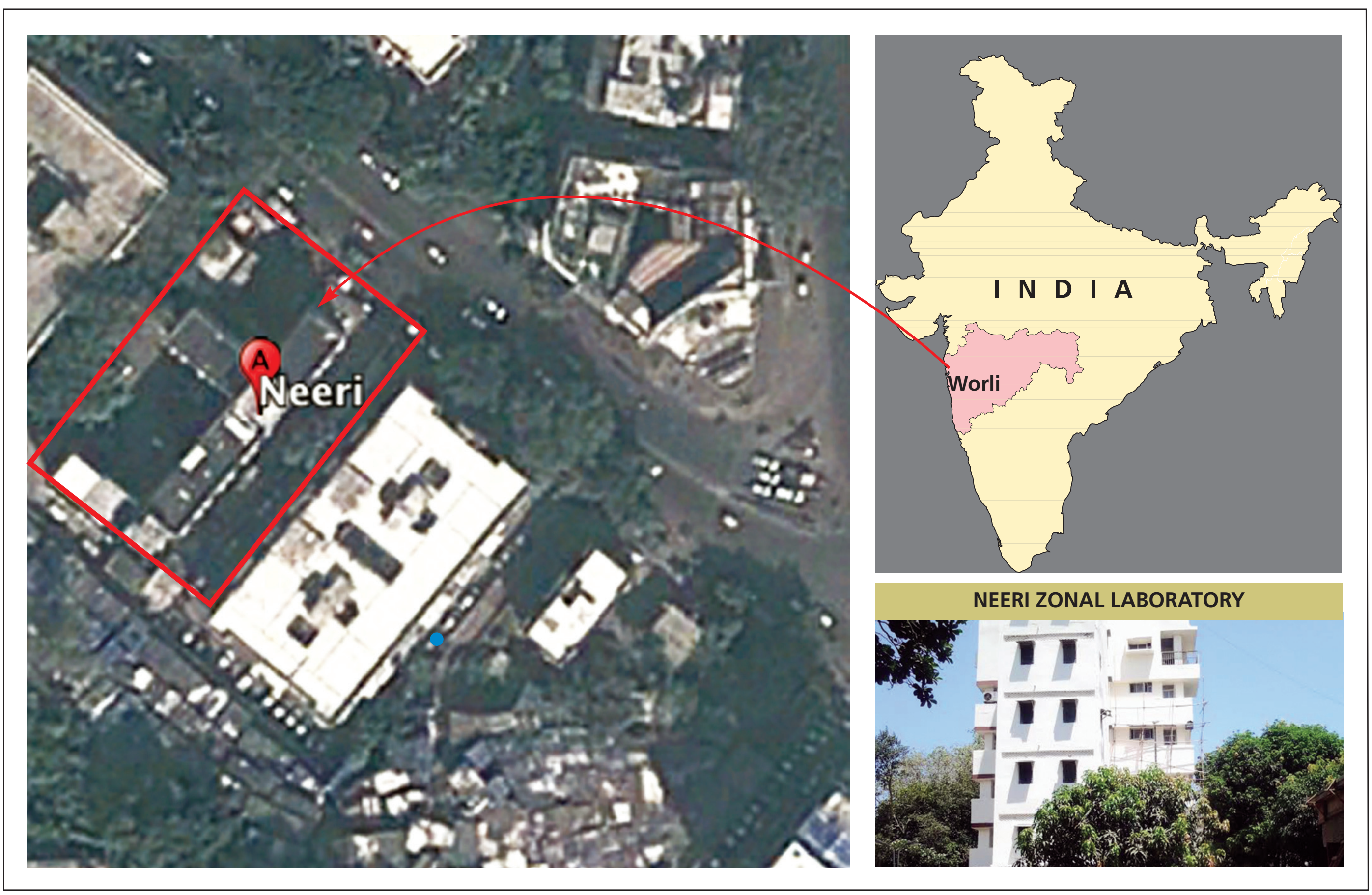
The zonal research laboratory of NEERI is located on the Anne Besant Road, Worli in Mumbai (see *Map 2: Location map of the NEERI Zonal Laboratory, Worli, Mumbai*).

The institute is functioning from a 5 storey building located on 2000 sq.m area. The institute caters to 80-100 persons per day which includes 40 working staff with 15-20 visitors and guests residing at the guest house. The institute has various laboratories, office and a small guest house.[22] The institute has a well maintained green area and plantation over 550 sq.m area. With increasing water scarcity in the rapidly growing metropolis and to avoid dependence on private water tankers the institute implemented the DWWT system based on phytorid technology to treat grey water generated for local reuse i.e. horticulture water requirements. The alternate tanker water supply for maintaining the green area is estimated to cost the institute ₹0.13 million per annum.

Decentralised wastewater treatment system

The DWWT system at the institute treats the grey water generated in the bathrooms, wash basins, laboratory's washbasins and kitchen. The project overview is summarised

Map 2 Location map of NEERI Zonal Laboratory, Worli, Mumbai



Source: *Google Map Image*, 2014

TABLE 5 Salient features of phytorid based DWWT system at NEERI

Parameters	Details of DWWT System
Year of implementation	2005
Technology detail	Phytorid Technology
Type of wastewater	Grey water (wastewater from the bath, wash basins, laboratories and kitchen)
Phytorid plant capacity	5 KLD
Phytorid plant area	10 sq.m
Wastewater reused (180 days)	0.9 million liter per annum (900 KLD)
Green area irrigated	550 sq.m
Capital cost of system (2005)	₹0.07 million
O&M costs (per annum) including electricity cost to pump	₹0.01 million
Savings (per annum)	₹0.13 million

Source: *CSE Team, 2014*

(*see Table 5: Salient features of phytorid based DWWT system at NEERI*).

Keeping in mind the potential of local reuse for meeting the water requirement for maintenance of green area the phytorid technology based DWWT system was implemented in 2005.[23] The system was designed and implemented by Dr Rakesh Kumar, Director Gr. Scientist & Head of the NEERI Zonal Laboratory assisted by his students.

The project is a very good example of DWWT implementation on institutional scale. The case study demonstrates treatment of wastewater near the source of generation and resource potential in terms of local reuse for meeting non-potable water requirements i.e. for maintaining the green landscape, plantations and cleaning of parking area.[22]

Technical specifications, design including O&M

The details of phytorid technology based DWWT system - design of treatment process, details of operation and maintenance, system performance (physico-chemical parameters of treated wastewater) and the benefits have been discussed in following sections:

Phytorid technology

Phytorid technology is a self sustainable technology developed by NEERI, CSIR in 2005 for sewage treatment. The technology has been designed on the principles of natural wetlands, an advanced level of the conventional technology. Two international patents were granted for this technology, Australia Patent No. AU 2003223110 A1, 2005 and Europe Patent No. WO2004/087584A1, 2005.[24,25]

The technology works on the ecological principles of a wetland and acts as a nutrient sink which helps in removal of pollutants from the wastewater. In the treatment system wetland plants, gravel/stones media and their associated microorganisms mimic natural wetland ecosystem processes for the treatment of wastewater. Wastewater flows through the filter bed and the microorganisms embedded in the roots of the

Salient features of phytorid technology

- Natural process based wastewater treatment
- No sludge generation or odour / smell
- Flexibility in design – can be constructed in series or parallel modules/cells depending on land availability and site conditions
- No energy consumption except pumping of water for reuse
- Treatment system can be constructed as either subsurface flow or free water surface systems
- Land area required between 1-2 sq.m per KLD and even less for grey water treatment
- O&M costs varies from ₹1000-2000 for a treatment system of capacity between 50-100 KLD including pumping cost for reuse
- No skilled labour required for O&M

plants. The pollutants in the wastewater are filtered, chemically transformed and biologically consumed. The technology is designed to treat sewage from small houses, residential societies, institutions, hotels and commercial complexes.[22-25] The technology can also be applied to urban *nallahs*/drains through a variant of the same concept.[26]

Treatment system, design and construction

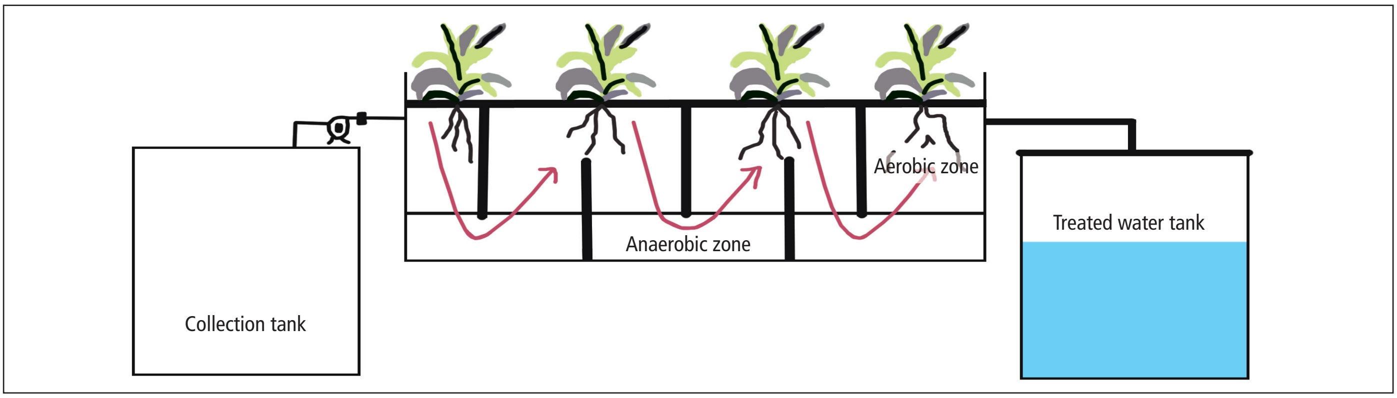
Phytorid based treatment system components include the following:

- A large bed of filter media (stones/ gravels) of different sizes
- Wetland plants such as *reeds/cattails* which have their roots and rhizomes in the gravel bed and shoots above the gravel surface
- Flow of wastewater from one end of the system, passing slowly through filter media and coming out at the opposite end (*see Diagram 3: Schematic components of phytorid technology based wastewater treatment system*)

The system consists of three zones:

- The inlet zone having media comprising crushed bricks or stones of various sizes connected to the treatment zone. The black water requires pre-treatment before entering the treatment zone while it is not required for grey water. Generally, a sedimentation tank or a septic tank may be introduced
- The treatment bed contains filter media (gravels, stones) of various sizes, a few baffles to ensure up and down flow of wastewater flowing through, plant roots and rhizomes and associated microbial communities. The roots and rhizomes give oxygen to the substrate (wastewater) creating oxidised and anoxic zones in its surroundings. The design of the bed creates temporal aerobic and anerobic zones that facilitate a wide range of biotic and abiotic processes. The filter materials also help in anchoring the wetland plant growth[24,25]
- The outlet zone consists of a treated water collection tank from where the water can be pumped out for reuse (*see Diagram 3: Schematic components of phytorid technology based wastewater treatment system*)

DIAGRAM 3 Schematic components of phytorid technology based wastewater treatment system



Source: *CSE TEAM*

The phytorid based wastewater treatment plant can be constructed as either subsurface flow or free water surface system but the former is more common (*see Diagram 4: Cross-sectional view of the horizontal sub-surface flow & Diagram 5: Cross-sectional view of the free flow system*).

Wastewater in subsurface flow type system is applied to cell/ system filled with porous media such as crushed bricks, gravels and stones. The hydraulics is maintained in a way that wastewater does not rise to the surface. The design for the system is critical as no seepage to ground is allowed. The length to width ratio of the structure is maintained in a way that no overflow occurs. In urban areas sub-surface flow is recommended to avoid mosquito breeding and problems related to odour.[24,25]

The system is based on the specific wetland plants such as *bulrushes, cattails, reeds* and *sedges*. The plants have internal gas spaces called aerenchymas throughout the plant's tissue that helps in oxygen transfer from the air to the roots and other parts of the plant species. The roots and rhizomes leak oxygen into the substrate creating aerobic zones around it. Plantation also helps in removing suspended solids through sedimentation and filtration as it obstructs the flow of wastewater and reduces velocities.[16]

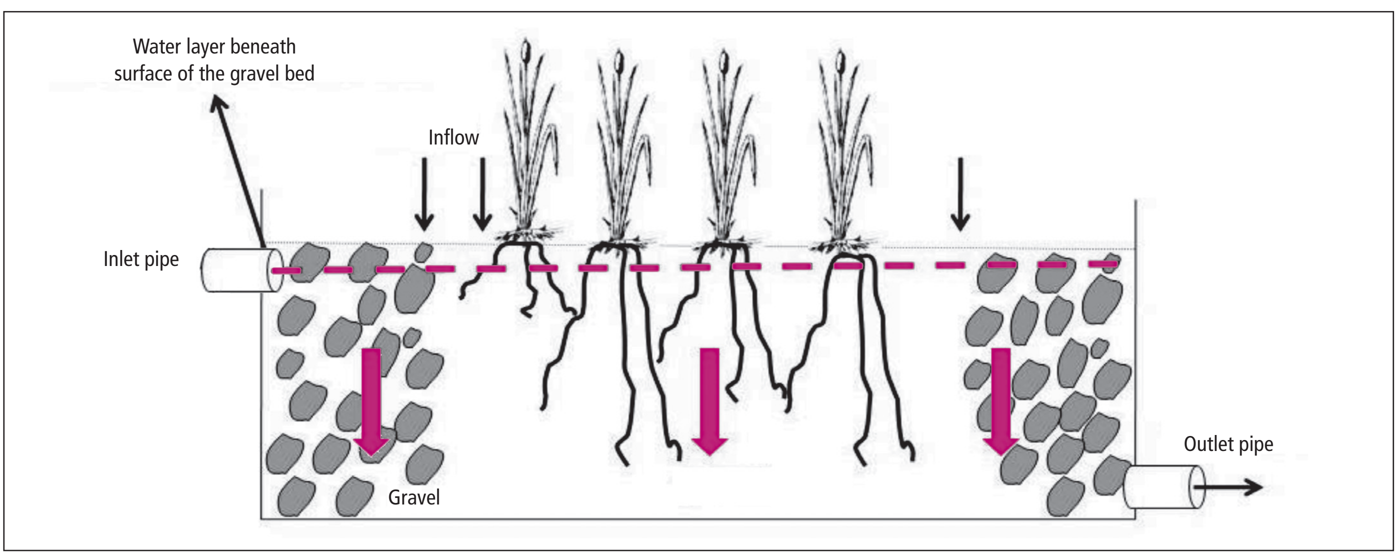
Aerobic bacteria consume and reduce suspended solids, uptake nutrients and reduce pathogens and odour from the wastewater. At lower depth of the bed much below the root zone is the anaerobic zone where anaerobic and facultative bacteria further reduce the pollutants.[23]

The media in phytorid technology plays an important role in terms of filtration, sedimentation of suspended solids and pathogens along with the sorption of phosphorus and dissolved organics. The other function of the media is to anchor wetland plants in the system. In most cases small sized filter materials are placed on the top of solids because smaller media provides more surfaces for the attachment of microbes which form the biological zone of the system (*see Table 6: Characteristics of media for phytorid technology system).*[22]

Both aerobic and anaerobic zones promote nitrification/ denitrification that remove nitrogen from the wastewater. Bacteria in wastewater oxidise ammonia to nitrite in an aerobic condition. The nitrite is then oxidised to nitrate aerobically. De-nitrification occurs under anaerobic condition when nitrate is reduced to gaseous forms in the litter layer of the treatment substrate.[24,25]

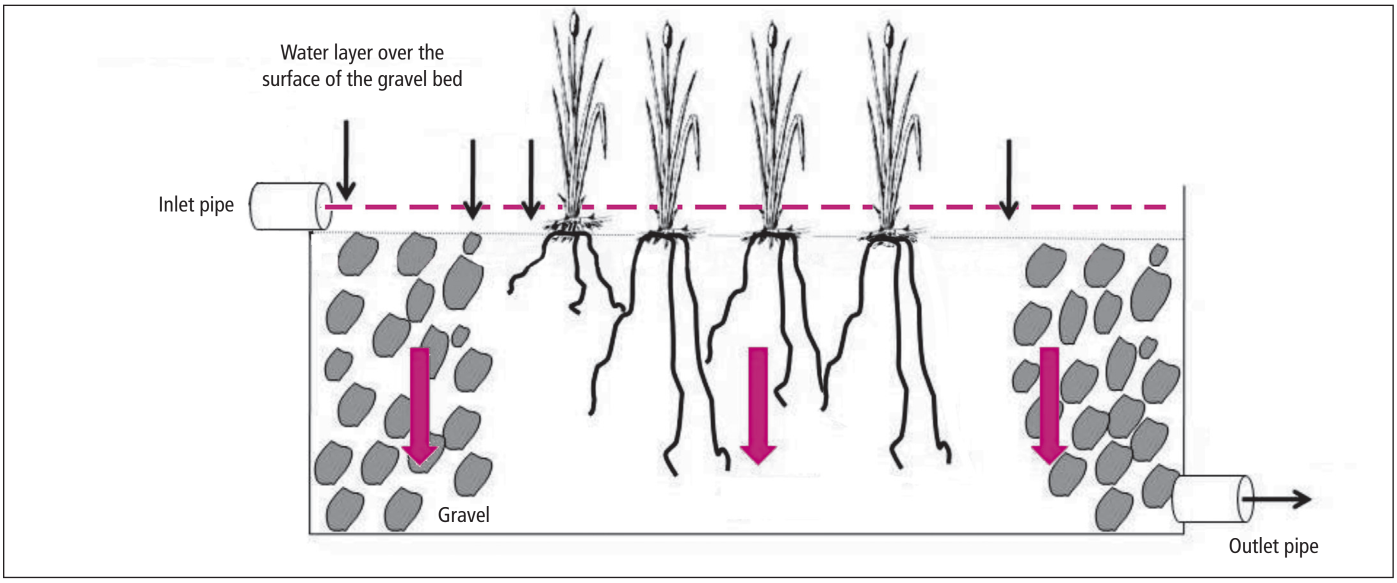
The phosphorus removal takes place through adsorption, filtration, sedimentation, complexation, precipitation and

DIAGRAM 4 Cross-sectional view of the horizontal sub-surface flow



Source: *S Rohilla and D Dwivedi 2013, 'Reinvent, recycle, reuse: Toolkit on decentralised wastewater management' (CSE)*

DIAGRAM 5 **Cross-sectional view of the free flow system**



Source: *S Rohilla and D Dwivedi 2013, 'Reinvent, recycle, reuse: Toolkit on decentralised wastewater management' (CSE)*

TABLE 6 **Characteristics of media for phytorid technology system**

Type	Effective size (mm)	Porosity (%)
Coarse gravel	2 - 5	32 - 42
Medium Gravel	32 - 65	40 - 60
Crushed brick	105 - 208	42 - 64

Source: R Kumar *et al*, 2004 'System and method of treatment of wastewater using plants' (Patent No. WO2004/087584A1)

uptake, while pathogen removal is achieved through a combination of natural die off, temperature, sunlight, predation and sedimentation. Biofilms filtering removes some of the pathogens by direct contact. The functioning potential of the technology depends on the native wetland plants serving the purpose of filtration, oxygen supply at depth along with aesthetics and only need to be pruned periodically. Hence the technology requires less maintenance and can be applied to various types and quantity of wastewater. The reduction of the treated wastewater for TSS varies from 80 to 95 per cent; BOD from 82 to 95 per cent; N from 70 to 75 per cent; P from 52 to 64 per cent and faecal coliform from 90 to 97 per cent. The treated wastewater is recommended for horticulture or irrigation water requirements.[22]

Excavation is followed by soling and laying of PCC/RCC layers to avoid seepage into the ground. Various cells are created for wastewater treatment depending upon the quality of wastewater and the type of reuse at the outlet. The side-walls of the treatment zone are constructed of concrete or brick work with plaster.

The cells are then filled with media consisting of sand gravel and crushed bricks of various sizes. In most cases a layer of small diameter material is placed at the top to allow for establishment of better plant roots. Piping is done to bring water from the source of generation to the treatment system followed by connection to the inlet zone. The inlet zone, treatment zone and the outlet zone is connected by underground pipe through the cells. Mechanical pumps are provided for pumping water wherever required.[22]

The construction cost of treatment system is dependent upon the capacity of the system, the length of pipelines to be laid and type of construction material used for the system. The cost varies between ₹14000 -35000 per KLD.[23]

The locally available wetland plants used in phytorid technology based wastewater treatment are - *Typha, Scirpus, Papyrus* and *Cannas*.

The untreated grey water or the black water is passed through the settler (septic tank or sedimentation tank), inlet zone and to the main treatment zone. Here, different types of bacterial population consume organic matter and other pollutants in their respective zones.

- The TSS of wastewater is removed by passing through the settler followed by another chamber filled with filter materials such as brick pieces, sand or gravel
- The TSS free wastewater flows into the treatment bed which has media with appropriate plant roots density and housing bacterial population. The wastewater flows uniformly in the horizontal direction, having baffle arrangements for improved mixing of the effluent with the bacterial population to enable contact with the root profiles of the plant
- At last, the treated water is collected from the outlet for either use after treatment or without further treatment or is disposed on land, lakes, river or marine water body

The optimum retention time for phytorid based effective wastewater treatment varies from 12-30 hours depending upon the capacity. The operation and maintenance cost varies from ₹1,000-2,000 for a system of 50-100 KLD capacity including the cost of pumping.[22,23]

Treatment system at NEERI zonal laboratory

The 5 KLD capacity phytorid based treatment system treats wastewater from the bathrooms, kitchens and laboratory

Settler of the phytorid based treatment system

Inlet zone with filter media

washings. The plant is located on 10 sq.m area. The system consists of a settler; an inlet zone filled with gravel media for the removal of suspended solids and planted cells containing media of large and medium sized gravels. The depth of the cell is 1.5 m and maintains a horizontal sub-surface flow. Baffles are provided to ensure upward and downward movement of the wastewater. Hence the bottom of the cell is anaerobic zone while the upper cell is aerobic zone.

The horizontal filter bed is provided with a slope of 1/200.The plants growing on the filter bed are *Scirpus*, *Typha* and *Canna.* After the treatment, the water is collected in a

Planted cell (Scirpus, Typha and Canna) of the phytorid system

collection tank from where it is pumped out for further usage. The treated water is free from suspended particle and doesn't have any bad odour.[22]

System performance including O&M

Phytorid technology based DWWT system has been in operation since 2005 at NEERI zonal laboratory, Mumbai. The system can operate with higher shock load of 10 per cent.

The reduction of BOD 85-90 per cent in the system reveals good performance. The performance result at outlet indicates the level of disinfection /treatment. Further it is clearly evident that the water after treatment can be safely used for non-potable water requirements such as horticulture, parking area cleaning etc as it meets all the standards prescribed by CPCB (*see Table 7: Treatment efficiency of phytorid treatment plant at NEERI*).

As part of regular maintenance, the plants need to be harvested periodically to maintain the wastewater treatment efficiency. The upper layer of media in the inlet zone requires scrapping or needs to be replaced periodically to avoid clogging due to the settlement of suspended particles. The maintenance cost is around ₹10,000 per annum including the cost of energy required to pump the treated water for local reuse.[23,28]

Socio-economic and environmental benefits

DWWT system treats 5 KLD wastewater that is locally reused for green area water requirement, car washing and for cleaning

TABLE 7 Treatment efficiency of phytorid treatment plant at NEERI

Parameters	Inlet (avg)	Outlet (avg)
pH	3.2	6.3
TSS (mg/l)	18.9	3.3
BOD (mg/l)	132	17
COD (mg/l)	187	38
Phosphate (mg/l)	25.57	0.82

Source: *S Tayade, 2014*

CSE TEAM

Collection tank of treated wastewater

CSE TEAM

Visual quality of wastewater – before and after treatment

of the parking area. The local availability of water for the non-potable water has reduced institute's dependence on municipal or supply through private tanker.

The average cost of water tanker (8000 liters per tanker) in Mumbai is ₹1000 – 1200, thus by using the treated water as alternate source of water about ₹0.13 million are saved annually. The green landscaped area in the institute will be self sustainable over the years without much depending on the municipal or tanker water supplies.[22]

CSE TEAM

Green landscape maintained on treated water

DWWT system caters to non-potable water requirements of the institute. The landscaped area and garden in the institute has provided added environmental benefits to the area and has improved aesthetics.

The phytorid technology based DWWT system at institute set up as demonstration project has been successful in creating awareness, information dissemination and a good example for practitioners to learn about the potential of natural wastewater treatment system. The in situ treatment and reuse of grey water upto 95 per cent would attract total of 5 credits on Indian Green Building Certification.[23] Various university campus and industrial areas/townships have now implemented similar system for wastewater treatment.

"I have been working here since last eighteen years as a lab assistant and also I am responsible for upkeep of the garden. Treated wastewater is used for the plants in our lawn and never had any health problems nor have I noticed any odour nuisance. Treated water is very clean"

— Dinanath, Laboratory Assistant and Incharge of Phytorid System

"I have been involved in implementing many phytorid system including one of 60 KLD capacity at Mahindra & Mahindra Ltd, Igatpuri. The system presents aesthetic appeal due to the presence of different plants, no odour and no nuisance in the surrounding. The workers sit and have their food in the vicinity of the plant inspite of knowing that it is a wastewater treatment plant"

— Dr. Ajay Ojha, Partner, Technogreen Environmental Solutions

Case study: Individual building scale

Residential Household Building, Sangli City (Maharashtra)

Objective

The wastewater treatment system for individual household building in Sangli city is based on fixed film biofilter technology (FFBT). The system treats domestic wastewater (both black and grey) and locally reuses treated water for meeting its horticultural water requirements – setting a good example of sustainable decentralised water management practice in unsewered residential area and demonstrating resource value of wastewater.

Location and water–wastewater scenario

The DWWT project is implemented in an individual household building located in Sangli City, Maharashtra. The present source of water supply to city is mainly from river Krishna. The average water supply in the city is around 106 lpcd. The city generates 50 MLD sewage but 55 per cent untreated sewage is disposed in the nallah and ultimately in river Krishna. Several areas in the city are still to be connected to sewer network.[29] The local body has a deficit of ₹10 million in water account and the city has very limited capacity to undertake new water or wastewater management projects.[30]

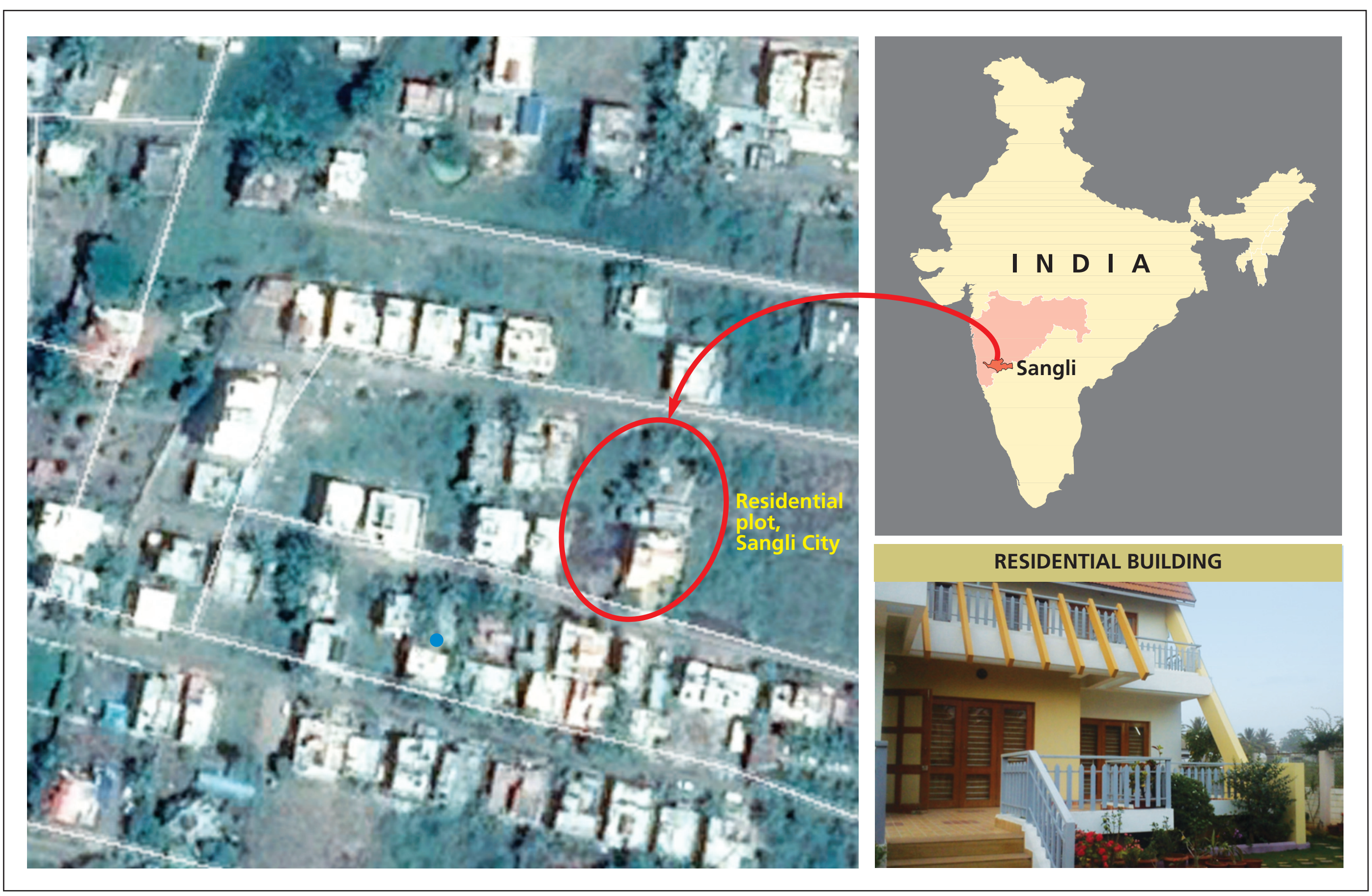
The individual residential building is situated on Dhamli road on suburbs of Sangli city. The area is still to be connected to municipal sewer network (see *Map 3: Location map of the Individual residential household building on Dhamli road, Sangli City*).

Decentralised wastewater treatment system

The building is residence of Mr Shripad Khire and his four member family. The DWWT system treats wastewater (both black and grey water).[31] The project overview is summarised *(see Table 8: Salient features of FFBT based DWWT system).*

Keeping in mind the potential of local reuse a DWWT system was designed and implemented by Dr. SD Khambe, Professor and Head, Department of Microbiology, Miraj Mahavidyalaya (Sangli). The project is good example of treatment of wastewater generated from individual household building demonstrating a potential of local reuse for meeting horticultural water requirements.

Map 3 Location map of the individual residential household building on Dhamli road, Sangli City



Source: *Google Map Image*, 2014

TABLE 8 Salient features of FFBT based DWWT system

Parameters	Details of DWWT System
Year of implementation	2010
Technology detail	FFBT
Type of building	Individual residential household (4 persons)
FFBT Plant capacity	1 KLD
FFBT Plant area	2.8 sq.m
Wastewater reused (180 days)	90 Kilo litre per annum (500 liters per day)
Green area irrigated	240 sq.m
Capital cost of system (2010)	₹35000
O&M costs (per annum)	₹800-1000
Savings (per annum)	₹10000

Source: *CSE Team, 2014*

Salient features of FFBT

- Natural processes based wastewater treatment – uses cultured microorganisms
- No smell / odour or nuisance
- Land area requirement ranges from 2-3 sq.m per KLD
- O&M cost of FFBT plant costs ₹2-3 per KLD per annum
- No skilled labour requirement for O&M
- Minimal energy consumption to pump water from collection tank for reuse

Technical specifications, design including O&M

The details of FFBT based system - design of treatment process, details of O&M, system performance (physico-chemical parameters of treated wastewater) and the benefits have been discussed in following sections.

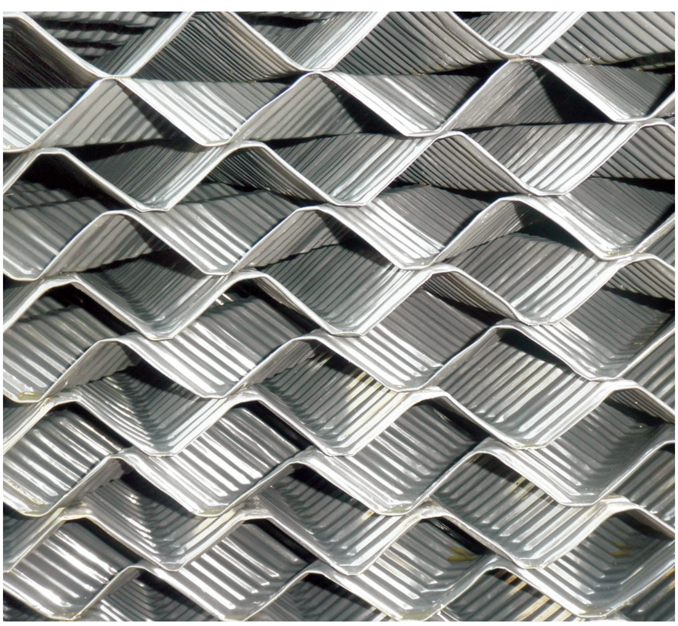
Fixed film biofilter technology (FFBT)

FFBT is a decentralised wastewater treatment technology. In 2004, Maharashtra Pollution Control Board made wastewater treatment systems mandatory for schools, hotels, institutions and individual house owners to dispose their waste in a proper manner and suggested FFBT as preference.[32] The technology is becoming popular among the individual house owners and residential colonies since it is environment friendly and economical compared to septic tanks and soak pits. The technology aims at bio-degradation of the wastewater contaminants by providing sufficient surface area required for the growth of micro-organisms (microbial culture) for optimum time duration. This retention time ensures maximum microbial growth. The culture consumes the contaminants from the wastewater and breaks them down as part of their food cycle.[32]

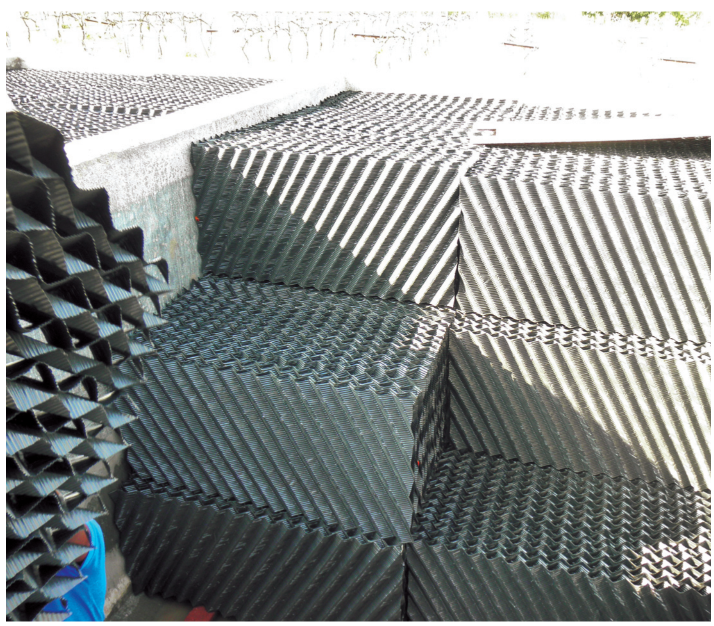
The microbial culture depends on the characterisation and treatability studies of the respective sites. In characterisation, wastewater of the site is monitored at regular intervals to check the variation in the quality (load) and quantity (flow). Whereas in the treatability study, the specific microorganisms are cultured depending on the characteristic of wastewater, containing microelements and micro nutrients that is required for effective biodegradation.[32,33]

The microbial culture contains naturally occurring carbon degrading organisms, lipolytic organisms (helps in degradation of oil and grease), proteolytic organisms (helps in the degradation of protein), nitrogen fixing, nitrifying and ammonifying organisms (for maintaining C/N ratio for effective degradation) along with phosphorus solubilising microorganisms (helps in converting phosphates into available form for better degradation) and actinomycetes (helps in the degradation of more complex organic matter) and removes odour and nuisance.[32,34,35]

The media used for attached growth can be stones/ gravels or modular PVC sheets arranged in a manner to provide maximum surface area and retention time for the growth of the microorganisms. The plastic media on which the microorganisms get fixed are more common in this technology

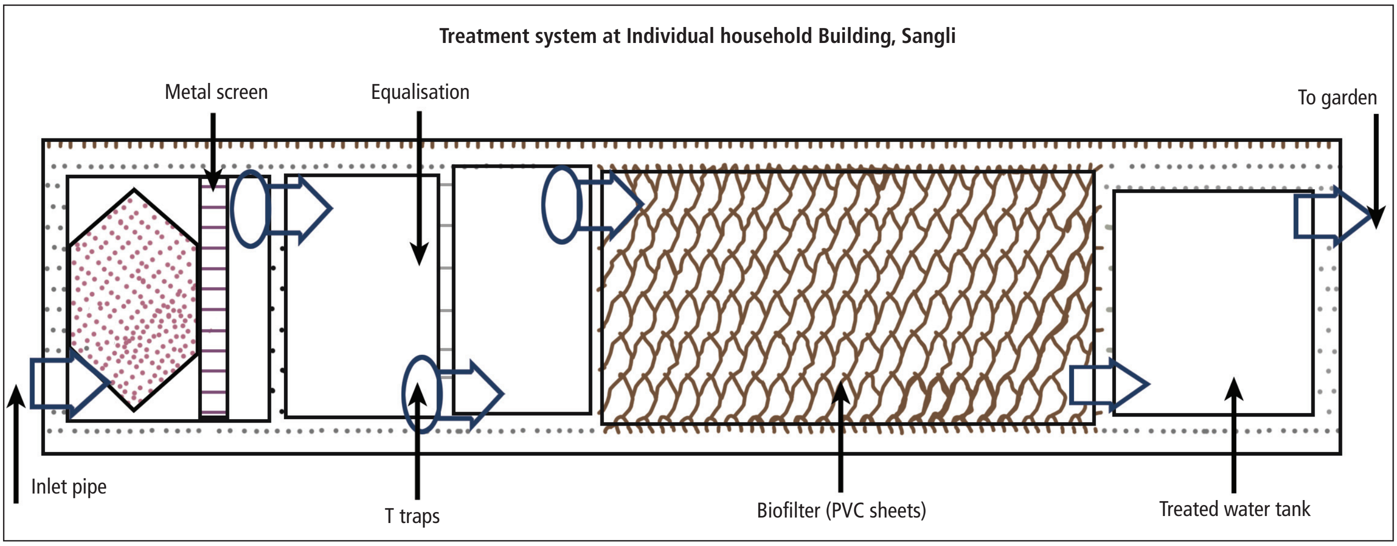


VIDHYADHAR P. SHENDGE



PVC media support made up of plastic in the above texture

DIAGRAM 6 **Schematic diagram showing the treatment process of FFBT**



Source: *SD Khambe*

due to long life span, uniform design for superior air and water flow throughout media and higher efficiency, easy cleaning and maintenance.[33]

Treatment system, design and construction

The wastewater is treated in three stages - preliminary treatment, primary treatment and secondary treatment as follows:

Preliminary treatment includes screening for which bar screens are provided, while primary treatment includes grit chamber/settler/septic tanks depending on the type of wastewater. This is followed by an equalisation tank which helps in equalising the flow of the wastewater before it enters the bio filter chamber. The water level is maintained 2 to 3 inches below the level of the biofilter. Secondary treatment is provided by the fixed biofilter. Microorganisms find surface area for their growth on the fixed film wherein the maximum treatment occurs.[31,32] The treated water is collected in a tank for usage thereafter *(see Diagram 6: Schematic diagram showing the treatment process of FFBT).*

The construction includes excavation followed by soling and laying of PCC/ RCC layer to avoid seepage into the ground.

V SHENDGE

Underground FFBT based wastewater treatment system

CSE TEAM

Piping and equalisation tanks

TABLE 9 **Treatment efficiency of FFBT – Individual household building, Sangli City**

S.No	Parameter	Inlet	Outlet	CPCB standard
1.	pH	8.32	7.20	6.5 - 8.5
2.	COD (mg/l)	580	40	<250
3.	BOD (mg/l)	260	4	<30
4.	Total Solids (mg/l)	1,130	680	
5	TDS (mg/l)	800	668	<2100
6	TSS (mg/l)	330	12	<30
7	Chlorides (mg/l)	60	60	<600
8	Sulphates (mg/l)	22	20	<1000
9	Oil & Grease (mg/l)	Nil	Nil	

Source: *SD Khambe, 2014*

Various chambers are created for screening, settling/ grit removal and equalisation chamber or septic tank followed by the biofilter chamber. Biofilter chamber is constructed with a baffle in between. It is covered with the PVC biofilters.

Pipes are laid from the source of generation to the treatment unit. The inlet and outlet pipes are placed diagonally opposite to each other in each chamber to avoid short-circuiting and backflow. Outlet pipe of each chamber is placed at a lower level of the inlet pipe. A swivel pipe is required to maintain the level of wastewater flow through the system.[32,33] A sump is required to be placed at the treated water outlet tank to pump out water for usage *(see Diagram 6: Schematic diagram showing the treatment process of FFBT).*

Treatment system at residential household building

The fixed film biofilter system at Mr. Khire's house is of 1 KLD capacity. The four toilets, bathrooms and the kitchen wastewater enters into the 2 equalisation tanks followed by the filter chamber of dimension 1.2 m x 1.2 m and a depth of 0.8 m. The biofilter consists of PVC material and the outlet pipes of each chamber are placed diagonally, opposite to the inlet pipes of the same chamber. This arrangement avoids back flow of wastewater. The final treated wastewater is then collected into a sump where the water is pumped out for maintaining the garden.[31,32]

System performance including O&M

The FFBT based treatment system at this residential building has been functioning since 2010. The treatment efficiency and overall performance of the system is being regularly monitored from government approved laboratory *(see Table 9: Treatment efficiency of FFBT – Individual household building, Sangli City).*

The results demonstrate almost 99 per cent organic material removal that clearly show good system performance and efficiency. The treated water is clean, no odour / smell and is fit for meeting gardening and landscaping water requirements *(see Photograph: Quality of water from FFBT based system).*[31-33]

CSE TEAM

Quality of water from FFBT based system

The O&M of a FFBT based treatment system is simple. To maintain good performance of the system, oil and grease layer should be skimmed regularly if a grease trap is present. The system also requires removal of settled grit and sludge and cleaning of the PVC filter every 1-3 years.[32]

In case of aerobic system, it should not be covered entirely but for safety purpose a grill can be used to cover. The system is a continuous flow system. In case the system requires shut down for 2-3 days, the microbial culture need to be added again. The O&M of the system costs around ₹500-1000 per annum.[32,33]

Socio-economic and environmental benefits

The individual household building is located on suburbs of a water scarce city and has no sewerage network. The septic tanks/ soak pits contaminate the groundwater and are cause of nuisance due to inadequate septage management mechanism in Sangli city.

The treatment of wastewater at source of generation and local availability of treated water for appropriate non-potable use at individual household building scale has not only resulted socio-economic benefits to the building owner but also provides environmental benefits. The treated wastewater is locally used for meeting horticultural water requirement of the household and used for maintaining 240 sq.m – plantation and landscaping *(see Photograph: Aesthetics and landscaping).*

A water tanker of 8000 litres capacity costs ₹800-1000.

"The treated water is very clean and doesn't smell. It is fit for gardening and landscaping purposes and such a system is beneficial to invest in if it is managed properly"

— Nitin Khandekar, Neighbour


CSE TEAM

Aesthetics and landscaping

In economic terms the availability of 90 KL of treated water per annum for meeting horticultural water requirement has resulted estimated ₹9000-10000 per year savings to the building owner that would otherwise be required to arrange water supply from private tankers. The well maintained garden and the landscaping with treated water have improved the aesthetics of the building. The trees and plantations attract butterflies and birds demonstrating the other environmental benefits.[36]

The project implementation and satisfaction of owner is creating awareness. The neighbours are now encouraged and planning to invest in installing FFBT based treatment system.


CSE TEAM

Plantation using treated wastewater


S KHIRE

Birds in garden where treated wastewater is used

"I feel proud to tell others that we are treating our wastewater to give water to our garden. When I show them our system people get inspired. We are better than others since we are at least not wasting water. Also, maintenance of this system is much easier than of a septic tank or soak pit"

— Mr Shripad Khire, Owner of the house with FFBT system at Sangli City

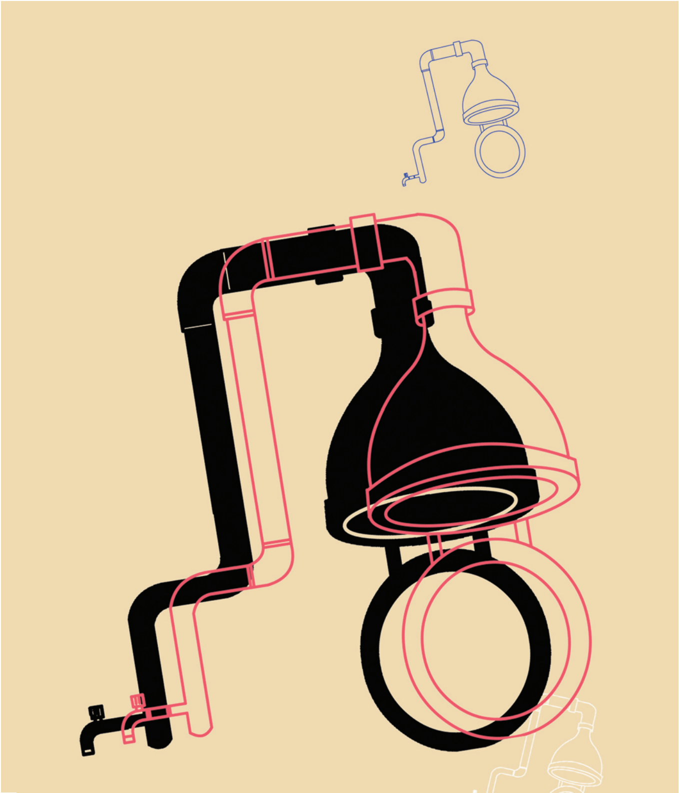
Implications and Conclusion

Water is a finite resource. There is no such thing as "new water". Each town / city need to understand that unless we are prudent, indeed frugal, with our use of this precious resource, there will never be enough water for all in towns and cities.

DWWT and local reuse is a good practice. It has more holistic and integrated view of wastewater generation, collection, treatment and disposal linking social – economical – environmental sustainability to the technology.

The report discusses with the help of three case studies the over arching framework of sustainable and affordable wastewater treatment at different scale – neighbourhood, institutional and individual household building and potential of local reuse within context. The case studies introduce a number of decentralised technology solutions and options yielding additional benefits that can replace or complement conventional wastewater management infrastructure in urban areas. The technologies make use of soil, plants and microorganisms – offering flexible treatment solutions depending on site and context and type of local reuse. The level of disinfection or treatment of wastewater decided the local reuse i.e. non-potable use for gardening and landscaping.

The framework presented in the report is drawn on examining potential of DWWT at different scale. But the framework presented in this report with help of case studies may not be applicable in all cases, and there may be other more specific context for particular cases.



It is expensive to build sewage network, but even more expensive to maintain it. Cities also find they can never repair enough.

The report with the help of case studies seek to encourage discussion within ULBs or water management organisations on potential of mainstreaming decentralised wastewater treatment and promoting local reuse - what they are doing at present and raising questions about what they want to do in the future.

It is time that municipal and other government bodies make determined efforts to mainstream decentralised wastewater treatment. The sustainable water management requires understanding the potential of local reuse.

REFERENCES

1. S Narain 2012, 'Excreta Matters: How urban India is soaking up water, polluting rivers and drowning in its own waste', Centre for Science and Environment
2. Anon, 'Report of the working group on Urban and Industrial Water Supply and Sanitation for 12th Five Year Plan (2012-2017)', Planning Commission, 2011, http://www.planningcommission.nic.in/aboutus/committee/wrkgrp12/wr/wg_indu_sani.pdf
3. S Rohilla and D Dwivedi 2013, 'Re-invent, recycle, re-use: Toolkit on decentralised wastewater management', Centre for Science and Environment
4. CPHEEO, 'Manual on sewage and sewerage', 2013, Ministry of Urban Development, New Delhi
5. Anon 2012, Status of water supply, wastewater generation and treatment in class-I cities and class-II towns of India, Central Pollution Control Board, http://www.cpcb.nic.in/upload/NewItems/NewItem_153_Foreword.pdf
6. Neale *et al* 2006, 'Preparing a case study: A guide for designing and conducting a case study for evaluation input', Pathfinder International
7. RK Yin 2009, 'Case study research: Design and methods (Vol. 5)'. California: Sage publications
8. John Creswell 2003, 'Research design: Qualitative, quantitative, and mixed method approaches'. Second Edition. Thousand Oaks: Sage Publications, Inc
9. HJ Rubin and IS Rubin 2005, 'Qualitative interviewing: The art of hearing data'. Second Edition. Thousand Oaks: Sage Publications, Inc
10. Environmental Protection Agency 2002, 'Community culture and the environment: A guide to understanding a sense of place' US EPA (EPA 842-B-01-003), Office of Water, Washington D.C.
11. Interview with Mr. Timothi, O&M Incharge of the SBT, Employee of Indian Navy, March 9, 2013
12. HS Shankar *et al* 'Process for treatment of organic wastes', Patent No: 6890438. 10 May 2005. US
13. HS Shankar *et al* 'Soil conditioning products from organic waste', Patent No: 7604742B2. October 2009. US
14. HS Shankar at al 'Process for treatment of organic residues', Patent Application MUM/384/26. April 2002. India
15. HS Shankar *et al* 'Process for treatment of wastewater', Patent Application MUM/383/26, April 2002, India
16. Interview with Dr. HS Shankar, Former Professor, Department of Chemical Engineering, IIT Mumbai, Powai, March 4, 2013; May 25, 2014
17. HS Shankar, 'Report on CAMUS-SBT, sewage treatment plants', http://www.che.iitb.ac.in/faculty/hss/CAMUS_SBT_IIT_overview.pdf, as viewed on May 28, 2014
18. AM Kadam 2013, 'Sewage recycling though soil biotechnology', Presented at CSE training on 'Designing decentralised wastewater treatment system for sustainable rural sanitation', Jaipur, June 4-7, 2013
19. AM Kadam *et al* 2009, 'Treatment of municipal wastewater using laterite-based constructed soil filter', Elsevier, Ecological Engineering 35(7), 1051-1061
20. AM Kadam *et al* 2008, 'Pathogen removal from municipal wastewater in constructed soil filter', Elsevier, Ecological Engineering 33, 37-44
21. Interview with Dr. AM Kadam, Sugham Paryavaran Vikalp Pvt. Ltd, March 9, 2013; February 10, 2014; March 5, 2014
22. Interview with S Tayade, Research Associate, NEERI, Mumbai Zonal Laboratory, CSIR February 10, 2014; March 20, 2014
23. Interview with R Kumar, Director Gr. Scientist & Head, NEERI, Mumbai Zonal Laboratory, CSIR, March 9, 2013 and February 10, 2014
24. R Kumar *et al* 'System and Method of treatment of wastewater using plants', Patent No. AU 2003223110 A1. 2005. Australia
25. R Kumar *et al* 'System and method of treatment of wastewater using plants', Patent No. WO2004/087584A1. 2004. Europe
26. R Kumar 2014, 'Lakes ponds: Pollution abatement and environmental sustainability', Presented at Regional workshop on 'Water resources conservation: Village ponds and lakes; New Delhi, February 25-26, 2014, http://www.cseindia.org/node/5321
27. Interview with Dr. AK Ojha, Partner, Technogreen Environmental Solutions, February 13, 2014
28. Interview with Dinanath, Laboratory Assistant, NEERI, Mumbai Zonal Laboratory, CSIR, February 10, 2014
29. Anon 2011, (Zero Draft) 'City sanitation plan', Sangli-Miraj-Kupwad Municipal Corporation
30. Anon 2011, 'Tool kit for public-private partnerships in urban water supply for the state of Maharashta, India', edited by Anouj Mehta, Asian Development Bank
31. Interview with SD Khire, Resident, Parshawnath Colony, Sangli City, February 11, 2014
32. Interview with Dr. S Khambe, Head, Department of Microbiology, Miraj Mahavidhyalaya, Miraj, February 10, 2014; February 12, 2014
33. Interview with V Shendge, Engineer (Operations), Aquarius Water Tech, February 10, 2014; February 12, 2014
34. S Facchin *et al* 2013, 'Biodiversity and secretion of enzymes with potential tility in wastewater treatment' Open Journal of Ecology 3(1), 34–47
35. AT Odeyemi *et al* 2013, 'Lipolytic activity of some strains of *Klebsiella, Pseudomonas* & *Staphylococcus Spp.* from restaurant wastewater and receiving stream' Scientific & Academic Publishing, Journal of Microbiology Research 3(1), 43-52
36. Interview with P Khire, Resident, Parshawnath Colony, Sangli City, February 11, 2014

ABBREVIATIONS

BOD	Biochemical Oxygen Demand
CCBP	Comprehensive Capacity Building Programme
CFU	Colony Forming Unit
COD	Chemical Oxygen Demand
CO_2	Carbon Dioxide
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organisation
CSE	Centre for Science and Environment
CSIR	Council of Scientific and Industrial Research
DO	Dissolved Oxygen
DWWTs	Decentralised Wastewater Treatment System
FFBT	Fixed Film Bioreactor Technology
IIT	Indian Institute of Technology
JnNURM	Jawaharlal Nehru Urban Renewal Mission
KLD	Kilo Litres per Day
Kwh	Kilo watt hour
LPCD	Litre per Capita per Day
MBBR	Moving Bed Bioreactor
Mg/L	Milligram per Litre
MLD	Million Litres per Day
N	Nitrogen
NEERI	National Environment Engineering Research Institute
O&M	Operation and Maintenance
P	Phosphorus
PCC	Plain Cement Concrete
PVC	Poly Vinyl Chloride
RCC	Reinforced Cement Concrete
SBT	Soil Biotechnology
Sq.m	Square Metre
STP	Sewage Treatment Plant
TDS	Total Dissolved Solids
TSS	Total Suspended solids
ULB	Urban Local Body
UV	Ultra Violet

GLOSSARY

Additives: A substance added to something in small quantities to improve or preserve it.

Adsorption: The accumulation of molecules of a gas/ liquid to form a thin film on the surface of a solid.

Aerobic: Relating to, involving, or requiring free oxygen.

Anaerobic: Relating to or requiring an absence of free oxygen.

Baffles: A wall structure generally made to provide for a barrier

Biodegradation - The condition or process of degrading or being degraded, wearing down by disintegration.

Bioindicator: An organism used as an indicator of the quality of an ecosystem, especially in terms of pollution.

Bioreactor: An apparatus in which a biological reaction or process is carried out

Clogging: Block or become blocked with an accumulation of thick, wet matter.

Culture: Maintain (tissue cells, bacteria, etc.) in conditions suitable for growth.

Degradation: The condition or process of breaking down into simpler molecules.

Denitrification: (denitrify) To remove nitrogen from.

Ecosystem: A biological community of interacting organisms and their physical environment.

Excavation: To remove the upper soil layers by digging or scooping out as the first step to start any construction work.

Fabrication: The action or process of manufacturing or inventing something.

Facultative microbes: They function in response to circumstances of the environment. They can grow both in aerobic and anaerobic conditions.

Geological: Of or relating to or based on the structure and substance of the earth, their history, and the processes which act on them.

Geophagus: Earth living, it is a genus in taxonomic classification of organisms.

Horticulture: The art or practice of garden cultivation and management.

Inorganics: Chemical compounds that do not contain Hydrogen, Oxygen and Carbon.

Microflora: Bacteria and microscopic algae and fungi, especially those living in a particular site or habitat.

Nitrification: The chemical process in which a nitro group is added to an organic compound (or substituted for another group in an organic compound)

Organics: Living or which once was living, consisting of Carbon, Hydrogen and Oxygen.

Pathogens: Disease causing micro-organisms.

Photosynthesis: The process by which green plants and some other organisms use sunlight to synthesise nutrients from carbon dioxide and water. Photosynthesis in plants generally involves the green pigment chlorophyll and generates oxygen as a by-product.

Precipitation: The action or process of depositing of a substance from a solution.

Respiration: The action of breathing, exchange of gasses.

Rhizomes: A continuously growing horizontal underground stem which puts out lateral shoots and adventitious (random) roots at intervals.

Rhizosphere: The region of soil in the vicinity of plant roots in which the chemistry and microbiology is influenced by their growth, respiration, and nutrient exchange.

Sedimentation: The phenomenon of sediment or gravel accumulating at the bottom under the influence of gravity.

Sewerage: The provision of drainage by sewers.

Shock load: A sudden increase in the load given to a system in terms of quality (organic load) or quantity (hydraulic load).

Soling: A process of leveling the surface by flattening before laying concrete.

Sorption: The term given to the process of adsorption and absorption together.

Underdrain: A small diameter perforated pipe that allows the bottom of a detention basin to drain.

Weathering: Breaking down of rocks, soils and minerals as well as artificial materials through contact with the Earth's atmosphere, biota and waters.

Wetland: A land area consisting of marshes or swamps. It is saturated by water all time of the year.

APPENDIX 1: Cost breakup of conventional wastewater treatment technologies

Name	Type	Advantages	Disadvantages	Land requi-rement (ha/MLD)	Capital cost (million ₹/ MLD/ year)	O&M cost (million ₹/ MLD/ year)
Waste stabilisation pond (WSP)	Conventional and natural	• Does not involve installation of electromechanical equipments • Robust system and can withstand hydraulic and organic shocks • Simple to construct, operate and maintain • Treated wastewater is safe to reuse for irrigation and aquaculture • High BOD reduction, nutrient removal and pathogen reduction	• High area requirement • If poorly maintained, odour nuisance and mosquito breeding problem	0.80 – 2.3	1.5 – 4.5	0.06 – 0.1
Duckweed pond	Conventional and natural	• Low operation and maintenance cost • Does not require skilled labour • Significant nutrient removal • Production of protein rich material which can be used as animal feed • No odour nuisance and mosquito breeding problem due to complete cover by duckweed	• Low pathogen removal due to reduced light penetration • Not suitable for extreme weather conditions especially in winters	2 – 6 (for 7 – 20 days of retention period)	1.5 – 4.5	0.18
Oxidation pond	Conventional and natural	• Less sludge generation as compared to aerobic processes	• Low suspended solid removal • Large land requirement • High power requirement due to aeration	–	30 – 80	0.2 – 1.0
Activated sludge process (ASP)	Conventional and natural	• Low area requirement • Performance is not affected by seasonal variations and wastewater characteristics	• High energy consumption • Highly skilled supervision for operation and maintenance of the plant • Continuous power supply is required for its operation as interruption in power supply even for short period of time can affect adversely	0.15 – 0.25	2 – 4	0.3 – 0.5
Upflow anaerobic sludge blanket (UASB)	Conventional and natural	• No external energy requirement • Recovery of gas is possible, having high calorific value • Low sludge generation • Can absorb hydraulic and organic shock loading	• Cannot meet the desired discharge quality standards without adequate post treatment • Effluent released is anoxic with high immediate oxygen demand, unsuitable for disposal in water body and for reuse • Poor coliform removal • Sensitive to seasonal temperature variations and low removal efficiency in winter • Release of corrosive and odorous hydrogen sulfide and ammonia in the air • Sludge washout from the reactor can result in instability leading to deteriorations in treatment performance	0.2 – 0.3	2.5 – 3.6	0.08 – 0.17
Biological trickling filter	Conventional and natural	• Lower process monitoring • Simple operation, does not require high skilled personnel for O & M • Generate sludge with better settling characteristics	• Blockages in distribution arm and clogging of the filter media • Require larger land area as compared to ASP	0.25 – 0.65	2 – 4 (slightly lower)	0.3 – 0.5 (slightly lower)
Rotating biological contractor (RBC)	Conventional and natural	• A higher level of treatment than conventional high-rate trickling filters due to a longer contact time (8 to 10 times greater); and • Reduced susceptibility to changes in hydraulic or organic loading than the conventional activated sludge process • It can be designed to remove 80–90 per cent of BOD but full nitrification can only be achieved when the organic loading rate is less than 5 g BOD/m^2/day	• Energy consuming • Skilled professional required for O&M	–	3.36	1.68
Fluidised aerobic bioreactor (FAB)	Emerging and electro-mechanical	• Primary sedimentation is not required • Small space requirement • Capacity to handle shock loads • Low and stabilised sludge production	• Periodic cleaning of the reactor bed is required as there is possibility of choking of the reactor bed • Excess biomass growth or low hydraulic loads can result in blockages • Long shutdowns may lead to septic conditions, and restart may involve a long stabilisation period	0.06	3 – 5	0.06 – 0.75

Contd...

Contd…

Name	Type	Advantages	Disadvantages	Land requi-rement (ha/MLD)	Capital cost (million ₹/ MLD/ year)	O&M cost (million ₹/ MLD/ year)
Moving bed bioreactor (MBBR)	Emerging and electro-mechanical	• Less space or underground requirement	• Energy consuming	0.055	10.8	63.81
Sequential batch reactor (SBR)	Emerging and electro-mechanical	• Excellent effluent quality • Smaller footprint because of absence of primary, secondary clarifiers and digesters • Biological nutrient (N&P) removal • High degree of coliform removal • Less chlorine dosing required for post disinfection • Ability to withstand hydraulic and organic shock loads	• Comparatively higher energy consumption • To achieve high efficiency, complete automation is required • Highly skilled operators needed • No energy production • Uninterrupted power supply required	0.055	11.5	45.12
Submerged aerobic fixed film process (SAFF)	Emerging and electro-mechanical	• Low and stabilised sludge production • Require less space for installation • High BOD removal, TSS reduction • Absence of odour and any other corrosive gases	• Problem of clogging of the filter • Reliance on propriety filter media • Requires skilled supervision • High energy consumption			
Membrane bioreactor (MBR)	Emerging and electro-mechanical	• Low hydraulic retention time than the conventional system • Very low footprint • Produce high quality effluent with small amount of sludge generation • Provision for modular expandability • Less susceptible to upsets due to flow variations	• Chemical cleaning of the filter is required every three to six months • High energy consumption	0.045	10.8	83.25
Vortex technology	Emerging and electro-mechanical	• It is a good substitute of planted filter as it requires less land area • The maintenance is easier as it is a closed and transparent system • No issue of local weather and soil quality as in the case of planted gravel filter • The vortex system is very effective in eliminating odours	• Require energy for its operation • Needs to be clubbed with other treatment (primary/secondary) systems	0.0001–0.0006	50,000 (₹/KLD/yr)	8500 (₹/KLD/yr)

APPENDIX 2: Cost breakup of new emerging decentralised wastewater treatment technologies

Name	Treatment Method	Treatment capacity	Reuse of treated water	Capital cost (₹/KLD)	O&M cost (₹/KLD/ year)	Features
Green bridge	Filtration, sedimentation, biodigestion and biosorption by microbes and plants	50 – 200 KLD/ sq m	In situ treatment of water bodies	200 – 500	20 – 50	• Suitable for in-situ treatment in rivers, flowing streams • No skilled labour is required for its operation and maintenance • It improves the overall aesthetics, aquatic life of the water body • Pollution load reduction is upti 80 per cent in general • Increase in dissolved oxygen (DO) from 150-200 per cent
Biosanitiser/ Eco chip	Bio catalyst-breaking the toxic/ organic contents	100 mg/ KLD	In situ treatment of water bodies, Horticulture	Chip costs 10,000 excluding civil / construction cost	NA	—
Nualgi	Phycoremediation (use of micro/ macro algae)- fix CO_2, remove nutrients and increase DO in water	1Kg treats upto 4ML	In situ treatment of lakes/ ponds, Increase in fish yield.	₹350 / MLD	9000 – 10,000/ML	• The growth of diatoms is very fast-starting within 5 minutes and continues as long as the nutrients lasts ie.,about 1 week to 10 days • 1 kg of Nualgi results in the release approximately 100kgs of oxygen • 100kg of Nualgi can treat 4 million litres of water
Bioremediation	Decomposition of organic matter using biological products	1 billion CFU/ml	In situ treatment of lakes/ ponds	Rs. 20,000-30,000/MLD for flowing water and Rs. 4000-5000/ML for still water	1.9 lakhs / MLD for flowing water 2.8 L / Acre in case of still water (for eg. Lakes)	• Reduce odour emission considerably • It is cost effective. No construction or additional infrastructure is required • Effective in removing highly toxic and health hazardous gas H_2S from the environment completely • These strains exhibit growth even at low temperature as low as 4 degree celcius and in the optimum pH range of 6-9 • The strain of bacteria maintains a satisfactory level of DO and therefore aerators, which consume high power, can be avoided or its use can be reduced • Controls the nutrient level in water thus helps in controlling "Eutrophication" process
Soil Bio technology	Sedimentation, filtration, biochemical process	5KLD – tens of MLD	Horticulture Cooling systems	10,000 – 15,000	1000 – 1500	• The process can be run on batch or continuous mode • No sludge production • Mechanical aeration is not required • The hydraulic retention time range from 30 mins to 1 hour without any pre-treatment • The overall time of operation is 6-7 hours. The bed is dried prior to next cycle of use.
Soil scape filter	Filtration through biologically activated medium	1 – 250 KLD	Horticulture	20000-30000	1800 – 2000	COD reduction in the range of 70-98% Area requirement is 1 sq m
DEWATS	Sedimentation, anaerobic treatment, plant rootzone treatment, oxidation process	Should be more than 1 KLD, but plants bigger than 1 MLD are also not feasible as would need extensive land	Horticulture, mopping floors, cooling towers and flushing	35,000 – 70,000	1,000 – 2,000	• Consist of several modules like settler, anaerobic baffle reactor, planted filter bed and a pond. • There's no need to have all the modules at each site, selection of modules depend on the quality of the water required after treatment • Settler helps in trapping the settlable solids whereas ABR helps in reducing BOD by 80-90%, while PFB helps in trapping the nutrients. Pond takes care of the odour • Minimal running cost, as no electro-mechanical equipment used
Ecosanitation Zero discharge toilets	Separation of faecal matter and urine		Flushing Horticulture Composting	30000 – 35000 (includes civil work)	35000 – 40000 (includes salary of the caretaker)	• Easy to install with no sewerage system requirement. • No electrical power supply or motor driven devices required • Hygienic conditions are maintained at the same level as in conventional water borne systems. • Can easily be operated and maintained by the community

Contd...

Name	Treatment Method	Treatment capacity	Reuse of treated water	Capital cost (₹/KLD)	O&M cost (₹/KLD/ year)	Features
Fixed Film Biofilter Technology (FFBT)	Settling and flow equalisation followed by enhanced natural degradation (biochemical process)	0.5 KLD to tens of MLD	Horticulture Car Washing	25,000 – 35,000	1000 – 2000	• Biofilter used may be stones, gravels, sand or PVC filter material whichever provides maximum surface area and is easily available. • Enhanced degradation of contaminants takes place in minimum area, since suitable micro-culture is added to the Biofilter cell
Phytorid	Settling followed by plant root zone treatment in specially engineered baffled treatment cells whch provides both aerobic and anaerobic treatment	5 KLD – tens of MLD	Horticulture	14,000 – 35,000	1,000 – 2,000	• Use of chosen wetland plants that are locally available • Retention time is between 5 – 7days • BOD and TSS removal average between 70-90% while faecal coliform is about 85-97% in treatment cells • Average nitrogen and phosphorus removal are in the range of 69-90%

KEY CONTACTS FOR SELECTED CASE STUDIES:

NAVAL CIVILIAN HOUSING COLONY

Dr. HS Shankar
Former Professor, IIT Mumbai
Vision earthcare Pvt Ltd
Shop No. 1, Neel Empire Building
Sector 25, Nerul East
Navi Mumbai – 400 076
Email: umashankar44@yahoo.com

Dr. Avinash M Kadam
Sugam Paryavaran Vikalp Pvt. Ltd
605/606 Exim Link Building, Opposite Container Yard
Mulund, Goregaon, Link Road, Nahur (W)
Mumbai – 400 080
Email: sughamparyavaran@gmail.com

NEERI, MUMBAI ZONAL LABORATORY

Dr. Rakesh Kumar
Director Gr. Scientist & Head
NEERI Mumbai Zonal Laboratory
89-B, Annie Besant Road
Worli, Mumbai – 400 045
Email: r_kumar@neeri.res.in

Dr. Ajay Ojha
Partner - Technogreen Environmental Solutions
202, Hem Opal, Plot No. 26
Ekta Society, Wakdewadi
Pune – 411 003
Email: technogreen.solutions@gmail.com

INDIVIDUAL HOUSEHOLD BUILDING, SANGLI

Shripad Khire (Owner)
Kaumudi, R.S. No. 373/ 1B/1
Plot No. 3 & 4, Parshwnath Colony
Dhamli Road, Sangli City – 416 416
Email: sdkhire@gmail.com

Vidhyadhar P. Shendge
Engineer (Operations)
Aquarius Water Tech
Ayush Complex, Aanand Park
Lovely Circle, Sangli City – 416 416
Email: v.shendge@aquariuswater.in

Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi 110 062
Ph: 91-11-40616000 **Fax:** 91-11-2995 5879
Email: cse@cseindia.org **Website:** www.cseindia.org